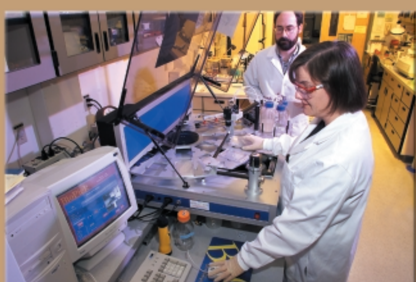
Institutional Plan

FY 2002–2007

October 2001
UCAR-10076-20

Lawrence Livermore
National Laboratory



1952
2002

NNSA
National Nuclear Security Administration

About the cover and divider pages

At Lawrence Livermore National Laboratory, we are beginning our 50th year of operation. Our history is rich with experience and accomplishments that have helped provide the nation's security—from the Cold War to today's war against terrorism. Our institutional memory is rich with images from the first days, through periods of growth, to today's exciting projects and dedicated staff.

The cover and divider pages draw our attention to projects from the past, present, and future—the mission-directed science and technologies that continue to make the Laboratory an exciting place to work.

Director's Statement: From international technical support for inspection teams in Iraq (background) to modeling hazardous and toxic atmospheric releases (right) to computer combat simulations for the nation's armed forces and law-enforcement agencies (left), Livermore plays an important role in national security.

Section 1: Breakthrough contributions to science and technology have been achieved as part of the Laboratory's quest to make civilian fusion power feasible in the 21st century. The 2XIIB, a magnetic fusion experiment in the 1970s (background), showed early Livermore "team science" in much the same way as the target chamber and laser glass (foreground) for the National Ignition Facility show multidisciplinary work today.

Section 2: We were created a national security laboratory, and that remains our primary focus. We gathered enormous amounts of data at the Nevada Test Site (background) from sophisticated diagnostics for underground nuclear weapons tests during the Cold War. Today, the Laboratory is a major contributor to the Stockpile Stewardship Program's mission to keep the nation's nuclear weapons safe, secure, and reliable with thermal, structural, and material tests (warhead of a W87 ICBM warhead, left; subcritical test, right).

Section 3: Engineering, chemistry, bioscience, and materials science disciplines at Livermore are the backbone of Livermore programs and the link to programs that meet enduring national needs. An early Laboratory precision machine shop (background) contrasts with today's multidisciplinary genome research at the Laboratory and the multilab Human Genome Institute (foreground).

Section 4: Education programs at Livermore have touched all levels of U.S. education, from grade school science demonstrations begun in the 1970s (background) to curriculum building for teachers (foreground) to internships and followships.

Section 5: From the first days of Lawrence Livermore National Laboratory, the founders understood the importance of computer advances to the success of our programs—from the Univac computer in the early 1950s to today's terascale computers for three-dimensional modeling.

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Institutional Plan
FY 2002–2007

Lawrence Livermore
National Laboratory

Department of Energy
University of California

October 2001
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Navigating the Institutional Plan

This year, the Institutional Plan is divided into the following sections:

Section 1. Laboratory Overview

Livermore's mission, roles, and responsibilities as a DOE national laboratory and the foundation for decisions about the Laboratory's programs and operations.

Section 2. Laboratory Science and Technology—National Security

A description of the situations, issues, and planned thrusts of Livermore's national security programs: stockpile stewardship, countering the proliferation and use of weapons of mass destruction, and other defense-related activities.

Section 3. Laboratory Science and Technology—Enduring National Needs

A description of the situations, issues, and planned thrusts of Livermore's programs to meet enduring national needs—in energy, earth and environmental sciences, bioscience and biotechnology, and fundamental science and applied technology, including Laboratory Directed Research and Development. The Laboratory's partnerships and collaborations with industry and academic institutions are also described.

Section 4. Laboratory Operations

Facilities and human resources information, including Laboratory staff composition and diversity and status of facilities with links to Contract 48 management and to Livermore's Comprehensive Site Plan.

Section 5. Appendices

- Program Resource Requirement Projections: Resource data for FY 2002–2007.
- Livermore Organization Chart.
- References for this Institutional Plan.

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Lawrence Livermore National Laboratory

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Director's Statement

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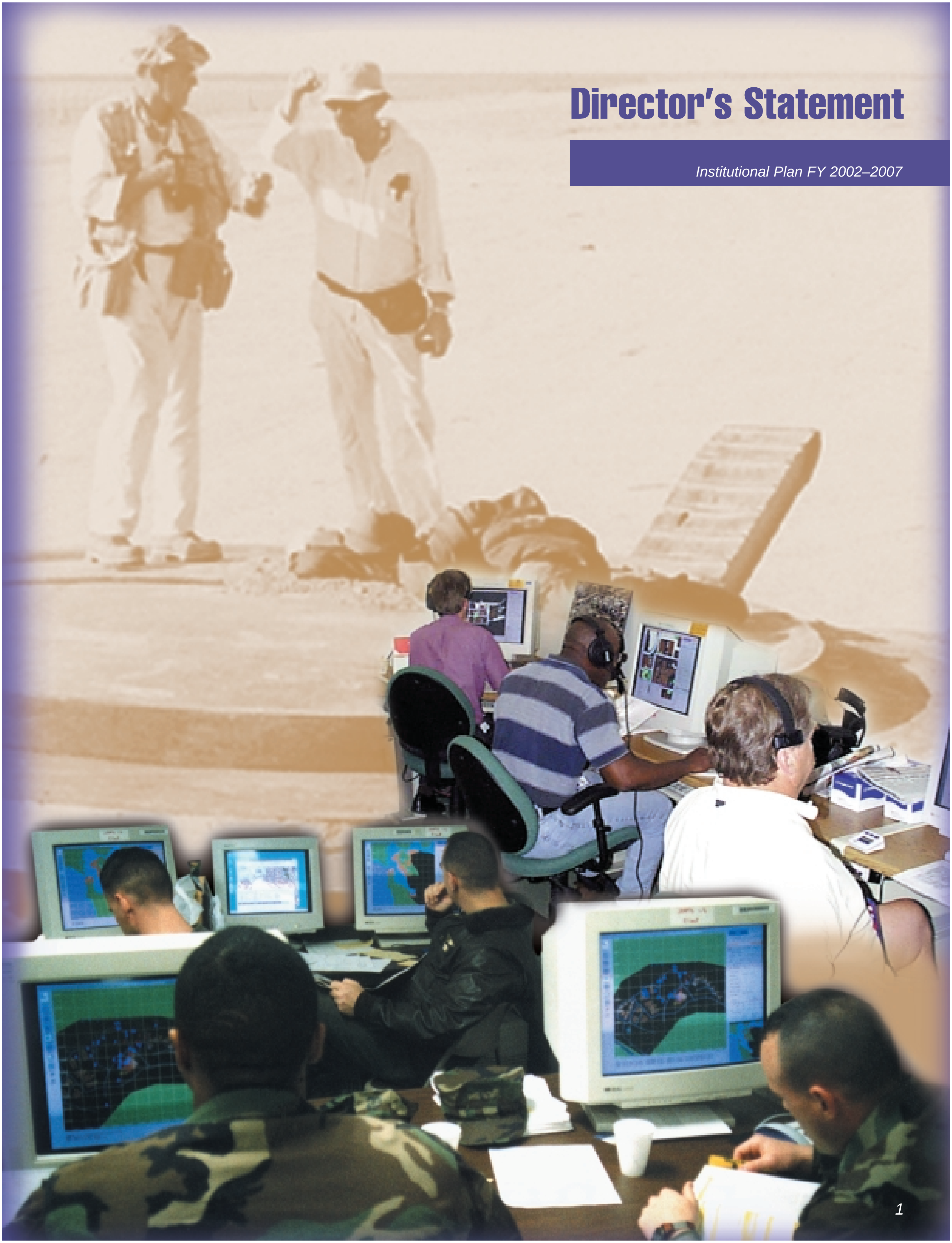


Director's Statement

C. Bruce Tarter
Director

AS we issue the *Institutional Plan FY 2002–2007*, Lawrence Livermore National Laboratory is beginning its 50th year of operation. Our Laboratory was founded by E. O. Lawrence and a remarkable group of young scientists to pursue innovative solutions to the nation's pressing needs to advance nuclear weapons science and technology. The Livermore branch of the University of California Radiation Laboratory opened its doors on September 2, 1952. Its budget was $3.5 million, and by the end of the fiscal year, Livermore had 698 employees. Currently, about 8,000 employees work at the Laboratory, which continues to be part of the University of California, and the annual budget is about $1.5 billion.

The threats to our nation have changed dramatically over 50 years—the Cold War through much of our history and now the war against terrorism. The Laboratory has continually changed to address the challenges of the day and anticipate future needs, keeping a central focus on national security. Now—as much as in 1952—innovative application of advanced science and technology is needed to cope with the threats that the world faces.

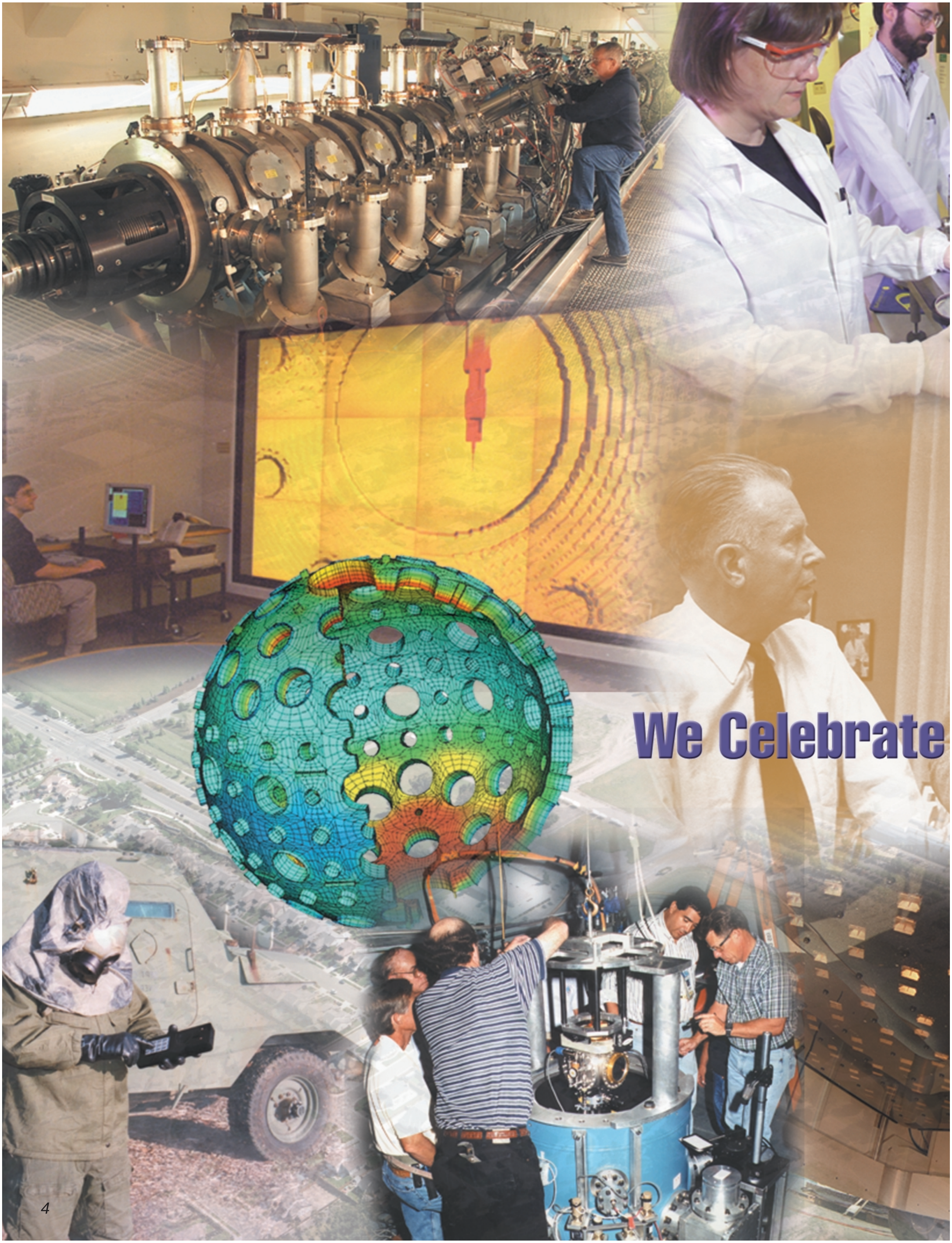
Our *Institutional Plan FY 2002–2007* describes the Laboratory's important responsibilities as part of the Department of Energy's National Nuclear Security Administration (NNSA), led by General John Gordon. We are providing the expertise that makes it possible for the United States to maintain a safe and reliable nuclear weapons stockpile. Laboratory researchers are also working with NNSA and other organizations to counter terrorism and to stem the proliferation of weapons of mass destruction.

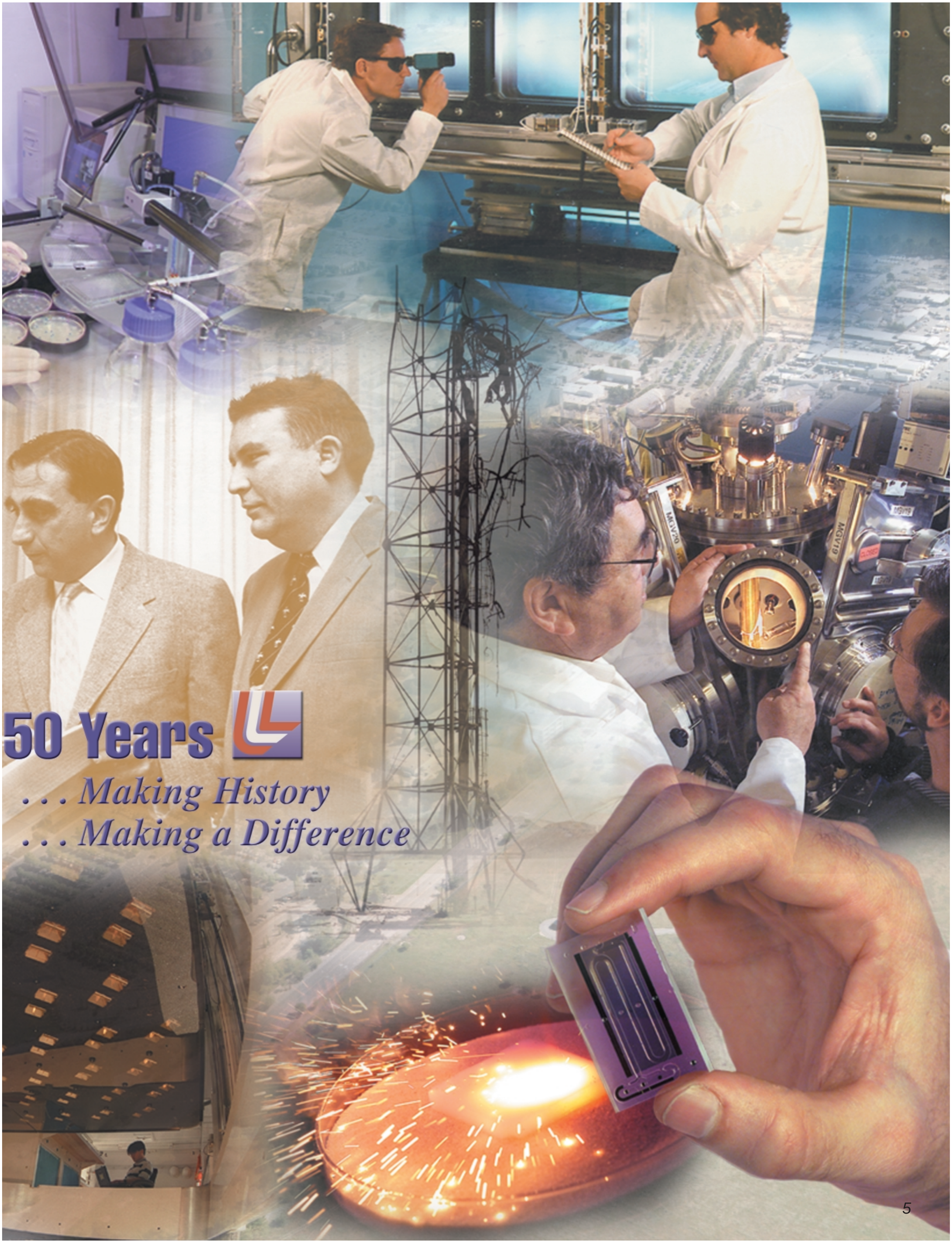
The Laboratory continues to apply its very special scientific and engineering capabilities to other important national needs—in energy, environmental quality, and biotechnology. These research activities align with the vital missions of the Department of Energy, and they focus on project areas that reinforce our national security work.

All of our research programs must be conducted in a safe and secure manner. As this Institutional Plan describes, we have been taking actions to sustain high standards of performance in all areas of operations. Substantial improvements have been made in Laboratory operations since performance measures became an integral part of the University of California's management process, which is now under the aegis of UC Vice President for Laboratory Management, John McTague. Our long-standing association with the University has also greatly contributed to the scientific and technical excellence of Livermore's programs.

Our current program accomplishments and our plans as an institution will help forge the future of NNSA and the continuing success of other programs in the Department of Energy. Our *Institutional Plan FY 2002–2007* describes how Lawrence Livermore National Laboratory will begin its second 50 years.

At Livermore, we are ensuring national security and applying science and technology to the important problems of our time.


We Celebrate


50 Years
. . . Making History
. . . Making a Difference

SECTION 1

Laboratory Overview

Laboratory Overview

AT Lawrence Livermore National Laboratory, we are ensuring national security and applying science and technology to the important problems of our time.

Lawrence Livermore National Laboratory was founded in 1952 as a nuclear weapons laboratory. National security continues to be Livermore's defining mission. The Laboratory has been administered since its inception by the University of California (UC), first for the Atomic Energy Commission and now for the National Nuclear Security Administration (NNSA) within the U.S. Department of Energy (DOE). Through its long association with the University of California, the Laboratory has been able to recruit a world-class workforce and to establish an atmosphere of intellectual innovation, which is essential to sustained scientific and technical excellence. As an NNSA laboratory with security and science central to its purpose, Livermore has an essential and compelling core mission and the capabilities to solve important, difficult, real-world problems.

Continuity in our mission. As this *Institutional Plan FY 2002–2007* highlights, our mission is clear, and we must continue to meet commitments in our research and development activities. We are responsible for ensuring the performance of weapon systems in the U.S. nuclear stockpile and for bringing into operation and applying significant new capabilities required for nuclear weapons stockpile stewardship. These include, most notably, the National Ignition Facility and ASCI White, a 12-trillion-operations-per-second supercomputer that is part of the Accelerated Strategic Computing Initiative (ASCI). In addition, we develop technologies and provide analysis capabilities that support U.S. nonproliferation objectives and contribute to the war against terrorism. The Laboratory is also committed to other major efforts in energy and environment, bioscience and biotechnology, and basic science that complement our national security efforts.

Changes in our environment. It is also a time of change for the Laboratory. The events of September 11, 2001, greatly affect the U.S. and all national security activities and organizations. Other changes in 2001 also have had a direct influence on Livermore. A new Administration is in office, and the forthcoming results of its national security reviews, its national energy policy, and its new initiatives will affect programmatic activities at the Laboratory. Change will also result from actions taken by the new National Nuclear Security Administration, which includes Livermore as one of its three national security laboratories. We continue to be managed by the University of California; however, the contract between DOE/NNSA and UC was restructured when it was extended in January 2001. There are greater demands on UC for oversight and higher expectations for Laboratory performance in areas such as safety and security. In addition, there have been many changes to the Laboratory's senior management team with nine associate director–level positions filled in 2001.

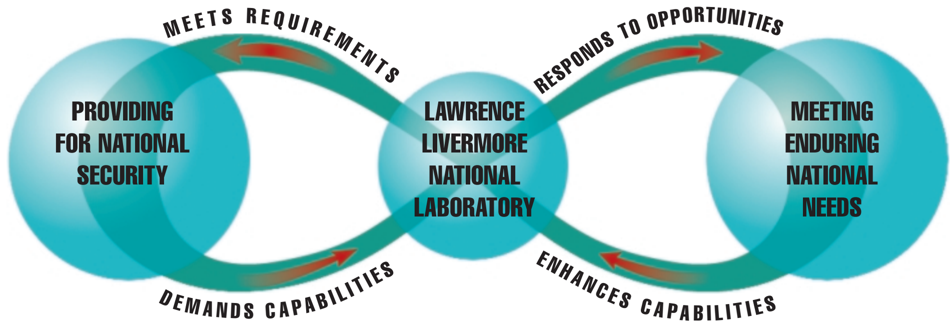


Figure 1-1. The Laboratory's mission. We meet requirements to provide for national security. This mission demands capabilities at the Laboratory that are used to respond to opportunities to meet enduring national needs through projects that enhance our capabilities.

1.1 Mission, Vision, and Goals

1.1.1 Mission

Lawrence Livermore National Laboratory is a premier applied-science national security laboratory. Our primary mission is to ensure that the nation's nuclear weapons remain safe, secure, and reliable and to prevent the spread and use of nuclear weapons worldwide. This mission enables our programs in advanced defense technologies, energy, environment, biosciences, and basic science to apply Livermore's unique capabilities and to enhance the competencies needed for our national security mission. The Laboratory serves as a resource to the U.S. government and a partner with industry and academia (Figure 1-1).

1.1.2 Vision and Goals

Our goal is to apply the very best science and technology to enhance the security and well being of the nation.

A Focus on National Security

National security is the defining responsibility of Lawrence Livermore National Laboratory. We are focusing the Laboratory's efforts on two of the

The Livermore Approach to Problem Solving

Multidisciplinary Research Teams. We form multidisciplinary teams tailored to meet the demands of each challenging problem. The teams combine scientific and engineering talent, and they draw from a diverse mixture of knowledge, skills, and experience to generate innovative solutions. Increasingly, research efforts entail partnerships with others outside the Laboratory.

An Integrated Approach to Research and Development. Research and development activities at Livermore range from fundamental science to production engineering of complex systems. We carry concepts all the way from scientific discovery to fully developed prototype products.

Large-Scale Experimental Science and Engineering Development. We design and develop technical products for our customers as well as large-scale experimental facilities, which we then use as tools to achieve program goals.

Computer Simulation of Complex Systems. Computer simulation is a cost-effective means for "conducting" a large number of complex experiments. Confidence in modeling results depends on careful validation through actual experiments. These simulations and experiments are mutually reinforcing.

nation's top priorities: ensuring the safety, security, and reliability of the U.S. nuclear stockpile and reducing the threats posed by weapons of mass destruction. We will continue to provide the world-class scientific and engineering capabilities that make it possible for the U.S. to maintain the national deterrent and take steps to stem the proliferation of weapons of mass destruction and combat their use against the nation and U.S. interests.

As the war against terrorism makes clear, security presents the Laboratory with significant challenges. As part of an integrated national effort, we must make major advances in science and technology to maintain confidence in the U.S. nuclear weapons stockpile in the absence of nuclear testing. Drawing on these advances and the special expertise of the Laboratory, we also work with various U.S. government agencies to improve international nuclear safety and prevent the proliferation and use of nuclear, chemical, and biological weapons by developing needed technologies and analysis tools. Because of the exceptional scientific and engineering capabilities present at the Laboratory to meet these needs, Livermore is a national resource to assist in the war effort through the development of advanced technologies to increase homeland security and the effectiveness of U.S. military forces.

Major Investments at Livermore

At the Laboratory, investments are being made in cutting-edge computational and experimental tools needed to help ensure that the U.S. nuclear weapons stockpile remains safe and reliable. Livermore will have scientific computing capabilities that offer the potential for revolutionary advances in many areas of science and technology as we make necessary improvements to simulation models of nuclear weapons performance. Livermore is also the site for the National Ignition Facility, which will be the world's largest laser system and will provide the means for investigating the thermonuclear physics of weapons, exploring the promise of fusion energy, and advancing science on many fronts (Figure 1-2). These major investments are shaping the future of the Laboratory.

Meeting Enduring National Needs

An exceptional staff with state-of-the art research capabilities will enable the Laboratory to respond to a broad range of vital national needs. With Livermore's emphasis on high-payoff results, many projects will entail significant scientific and technical risk. We will seek such challenges where Laboratory efforts can lead to dramatic benefits for the nation.

We will focus on the enduring missions of the Department of Energy and the program areas that positively reinforce our national security work. Livermore will pursue projects aimed at significant, large-scale innovations in energy production to ensure abundant and affordable energy for the future. Environmental efforts will be directed at demonstrating effective remediation technologies, advancing the science base for environmental regulation, and modeling more accurately regional weather and global climate conditions. We will also serve as an effective national technical resource for the management of nuclear systems and materials.

The Laboratory's bioscience research will advance human health through efforts focused on genomics and proteomics, disease susceptibility and prevention, and improved health care and medical biotechnology. In other fields, Livermore researchers will pursue science and technology initiatives that have the potential for major advances and that bolster the Laboratory's scientific and technological strengths. Increasingly, our accomplishments will be achieved through effective partnerships with others.

Focused Internal Investments

The foundation for Livermore's diverse set of research and development activities—now and in the future—is the Laboratory's science and technology base. Excellence in science and technology keeps the Laboratory vibrant and healthy and able to respond to new challenges. We will sustain our science and technology base through effectively managed internal investments in long-term research activities (such as Laboratory Directed Research and Development projects), research capabilities (such as terascale computers), and the Laboratory's infrastructure to provide an accommodating, modern work environment.

Investments in the Laboratory's staff are also critically important. Our scientific and technical successes would not be possible without the dedicated, outstanding efforts of all employees. We must continue to attract and retain a diverse, high-quality staff for future achievements. Employee development—ranging from continuing education to leadership and management training for supervisors—is a key part of our investment strategy. We must ensure that employees have the best skills, training, and tools to accomplish their current work and to prepare for career growth.

Safe, Secure, and Efficient Operations

Livermore's scientific and technological achievements will be made possible by safe, secure, and efficient operations and sound business practices.

Safety and security are the most important considerations in day-to-day operations. The Laboratory is committed to providing every employee and the community with a safe and healthy environment in which to work and live. Through the implementation of Integrated Safety Management, we will ensure that safety stays a top priority at the Laboratory. We are also taking specific steps to enhance security and will fully integrate security mechanisms into the workplace through the implementation of Integrated Safeguards and Security Management. These efforts to enhance security were redoubled in the wake of September 11, 2001. In view of the new threat, all NNSA sites are reevaluating their potential vulnerabilities and addressing the problems.

In addition, through a concerted, long-term effort to improve operations and reduce support and overhead costs, Laboratory business services are now faster, better, cheaper, and safer. Livermore has adopted best commercial practices whenever possible and has greatly improved business information systems by taking advantage of rapid changes in information technology. We will continue to strive for improvement.

1.2 Critical Capabilities

The Laboratory is a national resource with an extensive science and technology base and many specialized research capabilities and facilities. Livermore provides leadership in several broad research areas that are central to the Laboratory's mission.

1.2.1 An Extensive Science and Technology Base

Livermore programs are supported by a large technical base with nearly 3,000 scientists and engineers serving as career or term employees. A significant portion of the scientific staff is organized into "discipline" directorates—Chemistry and Materials Science, Computation, Engineering, and Physics and Advanced Technologies—and many of these people are matrixed, or assigned, to specific programs. Use of the matrix system fosters efficient transfer of technical knowledge among programs, enables staff members to develop wide-ranging skills and knowledge, and infuses projects with diverse ideas for solutions. As a result, the Laboratory has the ability to seize program opportunities,

Figure 1-2. Expertise in advanced lasers and associated technologies, necessary for the National Ignition Facility and other major projects for national security, provides program opportunities in inertial confinement fusion, advanced lithography, and other diverse scientific and industrial applications.

the agility to react quickly to technical surprises, and the flexibility to respond to programmatic changes.

The Laboratory's many research and development accomplishments demonstrate Livermore's leadership in several broad research areas.

High-Energy-Density Physics and Nuclear Science and Technology. For nearly 50 years, the Laboratory has demonstrated excellence in science and technology directed at the development of nuclear weapons and the harnessing of thermonuclear and fission energy for civilian power generation. We have broad expertise in nuclear science and technology as well as exceptional capabilities for investigating the properties of matter at extreme conditions (up to stellar temperatures and pressures) and the interaction of matter with intense radiation. This expertise will remain crucial for our national security programs. It will also be applied to develop innovative techniques for environmental cleanup, assist NNSA in the management of nuclear materials, improve technology for nuclear systems, and advance fundamental science in many areas.

Advanced Lasers and Electro-Optics. Livermore is the preeminent laser science and technology laboratory in the world. We are strongly focused on meeting design and construction goals for the National Ignition Facility. We are

Principal Research Centers and Facilities at Livermore

Center for Accelerator Mass Spectrometry—most versatile spectrometry capability in the world.
Chemistry and Materials Science Environmental Services Laboratory—wide-ranging chemical and radiochemical characterizations of environmental samples.
Computer Incident Advisory Center—DOE's watch and warning center for computer network defense.
Conflict Simulation Laboratory—state-of-the-art, interactive, entity-level conflict simulations.
Electron Beam Ion Trap Facility—unique facility for the study of highly ionized atoms at rest.
Engineering Technology Centers—cutting-edge research in Centers for Complex Distributed Systems, Computational Engineering, Microtechnology, Nondestructive Evaluation, and Precision Engineering.
Falcon Laser/Linac—facility for developing a source of ultrafast-pulse x rays.
Flash X-Ray/Contained Firing Facility—versatile hydrodynamic testing facility currently completing upgrades.
Forensic Science Center—world-leading forensic analysis and instrumentation.
Genome Center—facility for high-throughput genome sequencing and study of functional genomics.
Hardened Test Facility—capability for mechanical testing of weapons components.
High-Explosives Applications Facility—world's most modern high-explosives research facility.
Information Operations and Assurance Center—models and visualizations of information networks; analysis and simulations of attacks and responses.
International Assessments Center—national resource for evaluations of foreign weapons programs.
Large Optics Diamond Turning Machine—world's most accurate machine tool for fabricating large metal optical parts.
Long-Term Corrosion Test Facility—comprehensive evaluation service for corrosion on various candidate metals for nuclear waste containers.
National Atmospheric Release Advisory Center—real-time emergency predictions of hazardous substance releases.
4-MeV Pelletron—versatile particle accelerator for materials analysis and radiation effects studies.
Plutonium Facility—modern facility for nuclear materials research and testing.
Positron Microscope—world's most intense pulsed proton beam for studying material defects.
Secure and Open Computing Facilities—supercomputers and testbed for hardware and software development.
300-keV Transmission Electron Microscope—near-atomic-level chemical and structural analyses and images of complex materials.
Tritium Facility—activities to support target fabrication and decommissioning and recycling in inertial confinement fusion.
Two-Stage Gas Guns—phase-change predictions through experiments with metallic hydrogen.
Ultrashort-Pulse Laser—capability for equation-of-state, opacity, and other stockpile stewardship experiments.
Uranium Manufacturing and Process Development Facility—research facility for casting and forming processes.

also applying the Laboratory's expertise in lasers and electro-optics to meet other national needs, contribute to the competitiveness of U.S. industry, and address issues in basic science (see Figure 1-2).

High-Performance Scientific Computing. As part of the Accelerated Strategic Computing Initiative, over the 1994–2004 decade, we are acquiring successively more powerful computers with the goal of increasing computational speed and data capacity by a factor of 100,000. In July 2000, we took delivery from IBM of a 12-teraops computer (12 trillion operations per second), capable of performing calculations in 5 minutes that would have taken 40 days to complete in 1997. Construction of the Terascale Simulation Facility will prepare us for acquisition of a 100-teraops supercomputer.

While meeting the Laboratory's commitments to national security programs, we are making internal investments to ensure that all major programs at the Laboratory have access to terascale computers. These capabilities can potentially revolutionize scientific discovery and lead to unprecedented levels of understanding in biology and environmental science, improved modeling of weather and climate, the design of new materials, and advances in many areas of physics.

Materials Science. In support of Laboratory programs, we have developed wide-ranging expertise about materials. In addition to conducting fundamental research on the properties of materials, we engineer novel materials at the atomic or near-atomic levels. Livermore's stockpile stewardship responsibilities require researchers to understand in great detail the properties of very complex materials—ranging from plutonium to organic materials, such as high explosives—and how materials age in the presence of radiation and toxic materials.

Expertise in chemistry and materials science also provides critical support to many other Laboratory programs, such

From *Creating the Laboratory's Future . . .*

PROVIDING FOR NATIONAL SECURITY
"National security is the defining responsibility of the Laboratory."

MEETING ENDURING NATIONAL NEEDS
"Our focus will remain on the critical, enduring missions of the DOE and program areas that positively reinforce our national security work."

MISSION-DIRECTED SCIENCE AND TECHNOLOGY
"Livermore's strengths are well matched to DOE's needs. . . . We pursue major projects where we can make unique and valuable contributions. These activities build on and reinforce the Laboratory's key strengths."

AN OUTSTANDING WORKFORCE
"Challenging scientific programs, world-class research facilities, and a collegial environment are critical to attracting and retaining an outstanding workforce."

INVESTING IN THE FUTURE
"Excellence in science and technology will keep the Laboratory vibrant and healthy and able to respond to new challenges."

MANAGING OPERATIONS EFFECTIVELY
"Safe and efficient operations, sound business practices, and attention to the Laboratory's valuable resources make possible Livermore's technical achievements."

PARTNERSHIPS THAT CREATE CAPABILITIES
"We are involved in collaborations as a means to accomplish our goals, an expansion of the original E. O. Lawrence model of team science."

as environmental cleanup, nuclear waste disposal, and atmospheric modeling. In addition, we develop nanoengineered multilayer materials and other exotic materials, such as aerogels. These advances meet programmatic needs for highly efficient energy-storage components, ultralight structural materials, tailored coatings, and novel electronic, magnetic, and optical materials.

1.2.2 Specialized Research Capabilities and Facilities

Many specialized research capabilities and facilities exist at Livermore. Because of our overall size, the need for technologies and capabilities that do not exist elsewhere, and the fact that essential elements of our national security mission are classified, much of the necessary expertise to support programs resides within the Laboratory. For example, we have capabilities to develop state-of-the-art instrumentation for detecting, measuring, and analyzing a wide range of physical events. We also have significant expertise to support innovative applied-science efforts in advanced materials: precision engineering, microfabrication, nondestructive evaluation, complex-system control and automation, and chemical, biological, and photon processes.

1.2.3 Multiprogram Support for DOE

As a consequence of the Laboratory's extensive science and technology base and its many special research capabilities, we provide multiprogram support to DOE. This important relationship between the capabilities that Livermore has developed to fulfill its national security mission and its ability to make unique and valuable contributions in other DOE mission areas is a central feature of Livermore's mission statement (see Figure 1-1).

For example, with outstanding capabilities in laser science and technology, we support stockpile stewardship, pursue inertial confinement fusion physics, develop lasers for biotechnology and advanced manufacturing applications, and apply advances in laser technology to make breakthroughs in areas of basic science (see Figure 1-2). Our expertise in bioscience and bioengineering has applications in genomics research, bioremediation, environmental risk reduction, and biological warfare agent detection. Advanced scientific computing at Livermore supports stockpile stewardship, atmospheric modeling for emergency response and global climate prediction, computational biology, modeling for radioactive waste disposition and the movement of contaminants in groundwater, materials science modeling, and many other scientific areas (Figure 1-3).

1.2.4 Critical Skills in the Workforce

Livermore's principal asset is its highly talented workforce. The many programmatic achievements of the Laboratory would not be possible without the dedicated, high-quality efforts of all employees. The outstanding scientific and technical achievements of the staff are greatly valued. Breakthrough accomplishments are critical to the success of the Laboratory and provide the foundation for future programs to meet national needs. The many awards and honors won each year by Livermore employees are highlighted in the Laboratory's *Annual Report*.

The recruitment, continuing training, and retention of a diverse, skilled workforce are major issues. They are receiving a high level of attention to ensure the continuing health of the Laboratory and its vitally important national security programs. In particular, we face the absolutely crucial challenge of maintaining expert judgment about nuclear weapons issues. That challenge has been recognized from the onset of the Stockpile Stewardship Program, and attention to workforce and "critical skills" issues are a significant part of the Readiness in Technical Base and Facilities program thrust (see Section 2.1.4).

In addition, specific Laboratory-wide programs are aimed at recruitment and retention; increased workforce diversity;

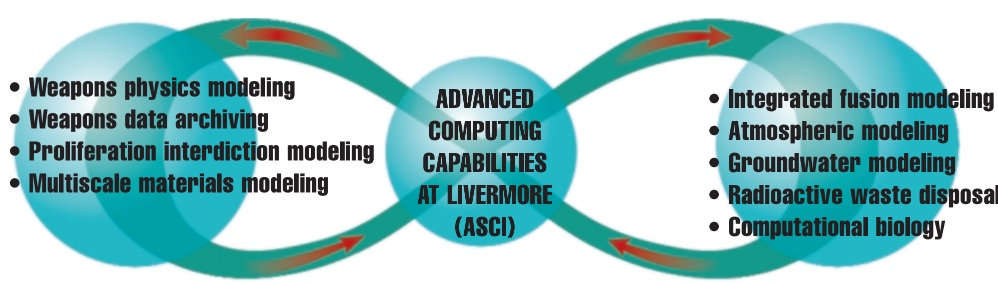


Figure 1-3. The Accelerated Strategic Computing Initiative (ASCI) and Livermore's advanced scientific computing capabilities, required for stockpile stewardship, enable us to respond to other program opportunities.

action against racial profiling; employee development; and leadership and management skills development. They are described in Section 4.3. Furthermore, Livermore has just completed a comprehensive, formal workforce survey to better and more systematically understand the issues facing employees and assess their views. Survey action teams have been formed to make recommendations for improvements in seven focus areas identified through the survey.

1.3 Strategy Development and Alignment

1.3.1 The Strategic Direction of DOE

The strategic direction of the Department of Energy is defined by the *DOE Strategic Plan* together with its *Annual Performance Plan for FY 2002*. The overall strategy defined by these documents is supplemented by the recently issued *National Energy Strategy* and forthcoming results and recommendations from ongoing reviews of the nation's military.

The DOE Strategic Plan. In September 2000, the DOE issued its latest strategic plan. It builds on the *U.S. Department of Energy Strategic Plan* (September 1997) and planning activities within the Department that have occurred since 1997. As in the previous document, the new plan articulates the Department's mission, vision for the future, core values, and strategic goals in Corporate Management and its four businesses: National Nuclear Security, Energy Resources, Environmental Quality, and Science. The general goals identified in DOE's Strategic Plan are:

- **National Nuclear Security.** Enhance national security through the military application of nuclear technology and reduce the global danger from weapons of mass destruction.
- **Energy Resources.** Promote the development and deployment of energy systems and practices that will provide current and future generations with energy that is clean, efficient, reasonably priced, and reliable.
- **Environmental Quality.** Aggressively clean up the environmental legacy of nuclear weapons and civilian nuclear research and development programs at the Department's remaining sites, safely manage nuclear materials and spent nuclear fuel, and permanently dispose of the nation's radioactive wastes.
- **Science.** Advance the basic research and instruments of science that are the foundations for DOE's applied missions, a base for U.S. technology innovation, and a source of remarkable insights into our physical and biological world and the nature of matter and energy.
- **Corporate Management.** Demonstrate excellence in the Department's environmental, safety, and health practices and management systems that support our world-class programs.

The DOE Annual Performance Plan. The strategic direction of the DOE is further defined by the DOE's *Annual Performance Plan for FY 2002,* which was prepared by the Department to meet requirements of the Governmental Performance and Results Act (GPRA) of 1992. The document is the fifth annual performance plan of DOE. It provides information to Congress and the public about the results the Department proposes to deliver for the requested FY 2002 budget.

The performance plan defines 51 general performance goals that are tied to 23 general goals specified in the strategic plan. Each of the general performance goals has associated final revised targets (usually several) for FY 2001 and proposed targets for FY 2002. Figure 1-8, p. 21, presented after discussion of the top priorities of the Laboratory, provides DOE's general performance goals in national security that entail significant activities at Livermore.

The National Energy Policy. *National Energy Policy*, the report of the National Energy Policy Development Group (May 2001), provides to the President a series of recommendations to promote dependable, affordable and environmentally sound energy for the future. The report envisions an integrated energy, environmental, and economic policy that builds on a comprehensive long-term strategy in which leading-edge technology will be used to provide reliable energy and a clean environment. The policy is designed to bring together the efforts of business, government, local communities, and citizens. It will lead to new demands on the research and development capabilities of the DOE and its national laboratories.

Reviews of the Nation's Military. In January 2001, the President asked the Secretary of Defense to conduct three reviews to create a new vision for the role of the nation's military in the 21st century. One of the reviews is examining the requirements of deterrence in the current security environment, including examination of the size of the future nuclear stockpile and the nation's needs for missile defense. The results and recommendations of the reviews may well affect DOE/NNSA's national security programs.

1.3.2 The Laboratory's Strategy

Livermore's Strategy Document. The Laboratory's strategy document, *Creating the Laboratory's Future*, provides the basis for this Institutional Plan. *Creating the Laboratory's Future* reflects our view of Livermore's responsibilities in meeting the strategic goals of DOE. The Laboratory's strategy was developed through the efforts of the five strategic councils at the Laboratory and the Policy, Planning, and Special Studies Office, which took the lead in synthesizing the work of the councils for senior management review.

Creating the Laboratory's Future describes Livermore's roles and responsibilities as a DOE/NNSA national laboratory and sets the foundation for decisions about Laboratory programs and operations. It presents the Laboratory's mission, vision, and goals (Section 1.1); work projects and initiatives in support of them; the science and technology strengths of the Laboratory that support our missions (Section 1.2); the management of operations at the Laboratory (and operations initiatives); and steps we are taking to prepare for the future.

Top Institutional Objectives for 2001–2002. As an extension to *Creating the Laboratory's Future*, a list of the Laboratory's top priorities identifies institutional objectives for 2001–2002 (Figure 1-4). The seven priorities on the list represent goals for the Laboratory as a whole—other important objectives for specific programs are not included. Our achievement of these objectives will help to strengthen the Laboratory as an institution and define long-term well-defined roles in program areas that are of national interest and importance.

Management Changes at Livermore. One of the Laboratory's top institutional objectives (Figure 1-4, objective 6) relates to senior management changes. With the appointment of seven new associate director–level managers in May 2001, most of the vacant senior-management positions have been filled. (See Section 5.2 for a current organization chart.) In the process of posting and filling the positions, the roles and responsibilities of some directorates have been realigned. In particular, formation of the Energy and Environment Directorate combines activities in what were two separate directorates, and the Physics and Advanced Technologies Directorate includes both the former Physics Directorate and portions of the former Lasers Program that are not part of the National Ignition Facility Programs Directorate.

In addition, four associate director positions were created to manage operational functions. This change ensures high-level attention to important Laboratory operational issues while it lessens line-management responsibilities in the Director's Office. The Deputy Director for Strategic Operations (DDSO) will have greater opportunity to focus on broader, more strategic issues and nurture effective working relationships with the new management teams at NNSA and the University of California.

With the new senior management team formed, the Laboratory is in the process of reviewing and revising the goals and membership of the strategic councils (and other committees). The councils are central to strategic planning because they provide Laboratory-wide strategic direction in their domain of responsibility. Three councils focus along major business lines of the Laboratory: the Council on National Security, the Council on Energy and Environmental Systems, and the Council on Bioscience and Biotechnology. The Council on Strategic Science and Technology focuses on issues pertaining to the scientific and engineering base at the Laboratory. In addition, there is a Council on Strategic Operations. The

Figure 1-4. Livermore's Top Institutional Objectives for 2001–2002.

1. Work to ensure that NNSA succeeds as an organization and in its long-range planning for stockpile stewardship and nonproliferation.
2. Establish and execute a robust, accepted path forward for the National Ignition Facility.
3. Work with DOE/NNSA and UC to effectively implement the restructured management and operating contract.
4. To better ensure recruitment and retention of skilled, diverse, and productive employees, add vitality to our workforce with emphasis on long-term R&D and improve the workplace environment using the employee survey to prioritize issues.
5. Successfully meet operational and administrative responsibilities in a cost-effective fashion with special emphasis on safety and security.
6. Fill open leadership positions and create a new senior management team that is organized to more effectively meet evolving operational and programmatic needs.
7. Respond to emerging national needs, new Administration initiatives and technical opportunities (e.g., in energy, biosciences, and defense) by developing new programmatic thrusts that apply Livermore's special capabilities, such as terascale scientific simulation.

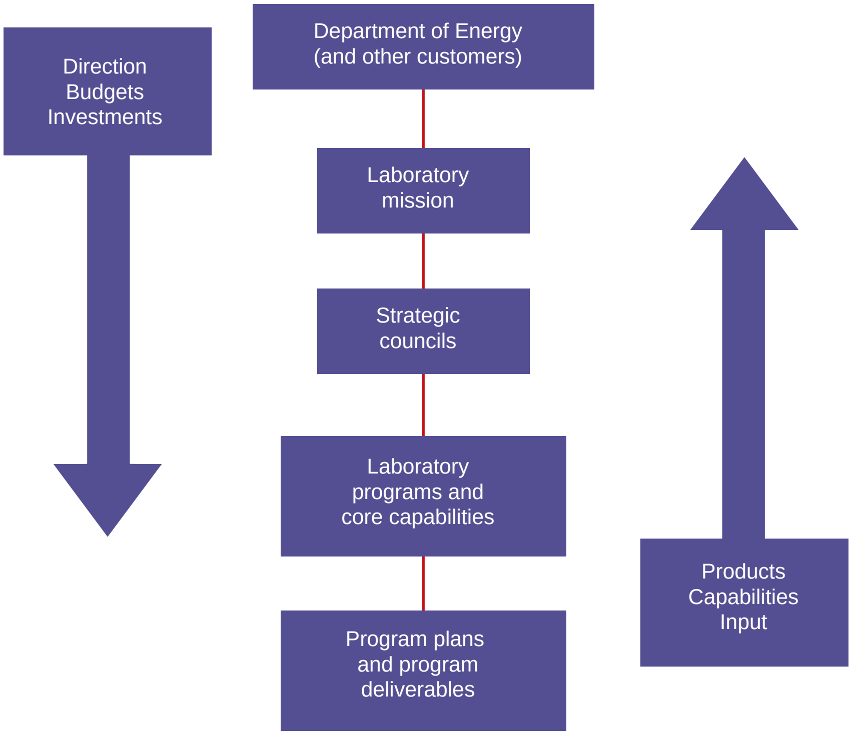


Figure 1-5. Development and alignment of Livermore's strategic plans are highly interactive processes involving the Department of Energy (as well as other customers) and the Laboratory's programs and strategic councils. Strategic direction and major new investments at Livermore, which flow down from the Department of Energy, are based on recognition of the Laboratory's capabilities, responsibilities, and current deliverables.

councils are responsible for formulating both tactical plans and the strategy for long-range program and resource development in their areas. They provide guidance and are part of the review process for Laboratory Directed Research and Development. As depicted in Figure 1-5, they also ensure that the strategic direction of planned actions and initiatives aligns with the strategic plans of the Department of Energy (and other customers).

The Laboratory as a whole is undertaking a new cycle of strategic planning beginning in autumn 2001. The new strategic plan will benefit from ideas for programmatic thrusts from the new management team and respond to newly emerging initiatives of the Administration and priorities of NNSA and DOE.

1.3.3 Alignment with DOE Strategy and Needs

Livermore's Principal Responsibilities and Major Programs. The Laboratory's mission statement—and essentially all the supporting material in *Creating the Laboratory's Future*—highlights the important interaction among Livermore's primary (national security) mission, the scientific and technical capabilities at the Laboratory, and programs to meet other enduring national needs. The direction of the Laboratory's national security programs—evident from the top institutional objectives—is discussed in Section 2 of this Institutional Plan. In providing for national security, Livermore's principal responsibilities are:

- Stewardship of the U.S. nuclear weapon stockpile.
- Stemming the proliferation of weapons of mass destruction.
- Responding to other important national security needs through the application of Livermore's science and technology.

Requirements to provide for national security demand unique capabilities at the Laboratory, which are also used to respond to opportunities to meet broader national needs. As discussed in Section 3 of this Institutional Plan, our focus is on the critical, enduring missions of DOE and program areas that reinforce our national security work. Where we can make unique and valuable contributions, Livermore pursues major projects directed at:

- Energy security and long-term energy needs.
- Environmental assessment and management.
- Bioscience advances to improve human health.
- Breakthroughs in fundamental science and technology.

We are able to make selected advances in many of DOE's mission areas, in part because our approach to research and development is multidisciplinary, integrating many disciplines with cutting-edge capabilities in multiple areas of science and technology.

For example, Livermore's Biology and Biotechnology Research Program is at the forefront of genomics research in part because of the Laboratory's engineering capabilities and success in developing technologies for high-speed sorting of individual chromosomes and for measuring distances between DNA markers. Bioscience expertise, in turn, is contributing to the development of novel bioremediation technologies for groundwater cleanup and portable minisensors for rapid, accurate detection and characterization of biological warfare agents in the field. Opportunities to meet a broad range of national needs are created by our other special capabilities, such as in advanced lasers (Figure 1-2) and advanced scientific computing (Figure 1-3).

Alignment with the DOE Strategic Plan. Continuing interactions of Livermore programs with DOE sponsors and senior Laboratory managers with DOE program secretarial officers (PSOs) greatly contribute to aligning the Laboratory's strategic direction with the *U.S. Department of Energy Strategic Plan* (September 2000). Moreover, as exemplified by the Stockpile Stewardship Program, key Laboratory program leaders and staff work with and provide information to assist NNSA and DOE PSOs in formulating DOE's strategic plans and direction. These activities feed back into the Laboratory's strategic planning process and assure that programs and strategies align with those of NNSA and DOE (Figure 1-6). Figures 1-7 and 1-8 illustrate alignment of Livermore's 2001–2002 top objectives with objectives defined in the *DOE Strategic Plan*.

Self-Assessments of Planning Success. In our self-assessment of Laboratory planning for DOE and the University of California (Section 1.4, page 17), we evaluate success and alignment with DOE's strategic direction and plans through consideration of four factors:

• Successful Programs and Partnerships. Sustained support for Livermore program activities is indicative of our efforts to align with DOE's plans and goals and of the executive branch and congressional recognition of the importance of the work and the progress being made. Increasingly, our programs are being pursued in partnership with other laboratories, academia, and industry. The formation and successful management of these partnerships also reflect on effective planning.

• Major Investments at the Laboratory. Successful planning is evident in the fact that major investments in capabilities and facilities are being made at Livermore. In addition, our special capabilities are being effectively used in programs sponsored by DOE and others.

• New Initiatives with DOE. Livermore is at the forefront of planning and execution of several new DOE initiatives, indicating that the Laboratory's plans are well aligned with those of the Department.

• Awards and Honors. The awards and honors we receive demonstrate the quality of science and technology at the Laboratory. A strong science and technology base makes it possible for us to be responsive to changing needs.

Department of Energy Strategic Plan	Creating the Laboratory's Future
National Security Enhance national security through military application of nuclear technology and reduce the global danger from weapons of mass destruction.	**• Providing for National Security** – Stewardship of the U.S. nuclear stockpile – Stemming the proliferation of weapons of mass destruction – Meeting new military requirements
Energy Resources Promote the development and deployment of energy systems and practices that will provide current and future generations with energy that is clean, efficient, reasonably priced, and reliable.	*"National security is the defining responsibility of the Laboratory."* *"Our focus will remain on the critical, enduring missions of the DOE and program areas that positively reinforce our national security work."*
Environmental Quality Aggressively clean up the environmental legacy of nuclear weapons and civilian nuclear research and development programs at DOE's remaining sites, safely manage nuclear materials and spent nuclear fuel, and permanently dispose of the nation's radioactive wastes.	**• Meeting Enduring National Needs** – Energy security and long-term energy needs – Environmental assessment and management – Nuclear materials stewardship – Advancement of biosciences to improve human health – Breakthroughs in fundamental sciences and applied technologies
Science Advance the basic research and instruments of science that are the foundations for DOE's applied missions, a base for U.S. technology innovation, and a source of remarkable insights into our physical and biological world and the nature of matter and energy.	

Figure 1-6. The missions and goals identified in the Laboratory's strategy document, *Creating the Laboratory's Future*, closely align with the strategic goals identified in the *U.S. Department of Energy Strategic Plan* (September 2000).

1.3.4 Anticipating and Responding to Future Needs

In addition to its programmatic responsibilities, Livermore—as a national laboratory—serves as a technical resource for the federal government to use in the development of effective public policy. To meet this responsibility, the Laboratory must maintain its vitality by anticipating and changing to meet evolving national needs. We work with DOE and other sponsors to anticipate the future needs of the nation, keep them apprised of emerging technical opportunities, and identify areas where science and technology can enhance security and national well being. To be effective, we must continue to be an integral and active part of the nation's science and technology infrastructure, participate in the national dialogue on important science issues, and be broadly recognized as a scientific leader.

Focused Internal Investments. We must continue to make internal investments that develop the skills and capabilities needed to meet customers' future needs. The present strengths of Livermore are, in large part, a product of investment choices in the past. An important source of internal investment is Livermore's Laboratory Directed Research and Development (LDRD) program. LDRD is an important tool we have for supporting research and development projects that will enhance the Laboratory's core strengths, nurture research efforts that expand scientific and technical horizons, and create important new capabilities so that the Laboratory can respond promptly and effectively to new missions and national priorities. Livermore's LDRD program has been very productive since its inception in FY 1985, with an outstanding record of scientific and technical output. Program accomplishments (highlighted in Section 3.3) are more fully described in Livermore's LDRD annual reports.

1.4 Evaluation of Performance

Livermore is one of three national laboratories managed and operated under a contract between the Department of Energy and the University of California (UC). When the DOE–UC contract was revised and extended in 1992, DOE and UC pioneered performance-based contracting as applied to government-owned, contractor-operated (GOCO) institutions. In 1997, DOE and UC extended the contract for five years and made changes to it to strengthen the performance-based management system introduced in 1992. In January 2001, the management and operating contract was modified to extend the contract term for an additional three years, through September 30, 2005.

Appendix F and Performance Measures. Appendix F of the DOE–UC management and operating contract contains performance objectives and measures that provide the basis for the performance management system. Performance is measured in three areas: (1) Laboratory management, (2) science and technology, and (3) administration and operations, which includes such items as environment, safety, and health (ES&H); security; business operations; facilities management; and human resources. Each year, Livermore provides UC with the *Science and Technology Assessment Report* (prepared by the Laboratory Science and Technology Office) and the *Appendix F Laboratory Management Self-Assessment Report and Appendix F Administration and Operations Self-Assessment Report* (coordinated by the Laboratory Office of Contract Management). UC reviews and uses these self-assessments to prepare an overall report that it submits to NNSA, and NNSA publishes an annual appraisal of the Laboratory's performance.

As shown in Figure 1-9, since the inception of the performance assessment system in FY 1993, the Laboratory has achieved very high ratings in science and technology and has markedly improved ratings in administration and operations since the first year. Our performance evaluation in FY 2000 was "excellent" in science and technology and "excellent" in administration and operations.

Appendix O and Performance Improvements. In January 2001, when the DOE–UC management and operating contract was extended for three years, it underwent a major rewrite. The contract was restructured to strengthen management accountability at UC and the laboratories and to provide for improved performance at Livermore and Los Alamos national laboratories under five Appendix O program performance initiatives:

- Management Accountability—to strengthen UC management accountability for laboratories, including the successful accomplishment of commitments in the contract.
- Safeguards and Security Management—to ensure that each employee is directly responsible for performing work safely and securely; to improve safeguards and security (S&S) management; and to instill public confidence in S&S management at the laboratories.
- Facilities Safety (including Nuclear Facilities Operations)—to institutionalize best practices in facility

Figure 1-7. Alignment of the DOE Strategic Plan with Livermore's Top Institutional Objectives for 2001–2002.

DOE Strategic Plan Objectives		LLNL objectives[a]
National Nuclear Security		
NS1:	Maintain and refurbish nuclear weapons in accordance with directed schedules to sustain confidence in their safety, security, and reliability, indefinitely, under the nuclear testing moratorium and arms reduction treaties.	1,2,4,6
NS2:	Achieve the robust and vital scientific, engineering, and manufacturing capability that is needed for current and future certification of the nuclear weapons stockpile and the manufacture of nuclear weapon components under the nuclear testing moratorium.	1,2,4
NS3:	Ensure the vitality and readiness of DOE's national nuclear security enterprise.	1,2,3,4,6
NS4:	Reduce the global danger from the proliferation of weapons of mass destruction (WMD).	1,4,7
NS6:	Ensure that the Department's nuclear weapons materials, facilities, and information assets are secure through effective safeguards and security policy, implementation, and oversight.	3,5
Energy Resources		
ER3:	Increase the efficiency and productivity of energy use, while limiting environmental impacts.	6,7
ER5:	Cooperate globally on international energy issues.	7
Environmental Quality		
EQ1:	Safely and expeditiously clean up sites across the country where DOE conducted nuclear weapons research, production, and testing or where DOE conducted nuclear energy and basic science research. After completion of cleanup, continue stewardship activities to ensure that human health and the environment are protected.	6,7
EQ2:	Complete characterization of the Yucca Mountain site and, assuming it is determined suitable as a repository and the President and Congress approve, obtain requisite licenses, construct, and in FY 2010, begin acceptance of spent nuclear fuel and high-level radioactive wastes at the repository.	6,7
Science		
SC1:	Provide the leadership, foundations, and breakthroughs in the physical sciences that will sustain advancements in our nation's quest for clean, affordable, and abundant energy.	2,4,6,7
SC2:	Develop the scientific foundations to understand and protect our living planet from the adverse impacts of energy supply and use, support long-term environmental cleanup and management at DOE sites, and contribute core competencies to interagency research and national challenges in the biological and environmental sciences.	4,6,7
SC3:	Explore matter and energy as elementary building blocks from atoms to life, expanding our knowledge of the most fundamental laws of nature, spanning scales from the infinitesimally small to the infinitely large.	4,6,7
SC4:	Provide the extraordinary tools, scientific workforce, and multidisciplinary research infrastructure that ensure success of DOE's science mission; and support our nation's leadership in the physical, biological, environmental, and computational sciences.	2,4,6,7
Corporate Management		
CM1:	Ensure the safety and health of the DOE workforce and members of the public and the protection of the environment in all Departmental activities.	1,3,5,6
CM2:	Manage human resources and diversity initiatives and implement practices to improve the delivery of products and services.	1,3,4,5,6
CM3:	Manage financial resources and physical assets to ensure public confidence.	1,2,3,5,6
CM4:	Manage information technology systems and infrastructure to improve the Department's efficiency and effectiveness.	1,3,5,6
CM5:	Use appropriate oversight systems to promote the efficient, effective, and economical operation of the Department of Energy.	1,3

[a]Number of objective from Figure 1-4.

Figure 1-8. The DOE Strategic Plan Objectives (NS1, etc.) in national nuclear security and their general performance goals (NS1-1, etc.) to which Livermore contributes.

NS1: Maintain and refurbish nuclear weapons in accordance with directed schedules to sustain confidence in their safety, security, and reliability, indefinitely, under the nuclear testing moratorium and arms reduction treaties.

NS1-1: Maintaining stockpile confidence.

NS2: Achieve the robust and vital scientific, engineering, and manufacturing capability that is needed for current and future certification of the nuclear weapons stockpile and the manufacture of nuclear weapon components under the nuclear testing moratorium.

NS2-1: Conducting campaigns.

NS3: Ensure the vitality and readiness of DOE's national nuclear security enterprise.

NS3-1: Ensuring enterprise vitality and readiness.

NS4: Reduce the global danger from the proliferation of weapons of mass destruction (WMD).

NS4-1: Conducting nonproliferation and verification research and development.
NS4-2: Improving international nuclear safety.
NS4-3: Supporting arms control and nonproliferation policies.
NS4-4: Strengthening Russia's materials protection, control, and accounting.
NS4-5: Assuring a transparency in the conversion of Russian highly enriched uranium.
NS4-6: Reducing inventories of surplus weapons-usable fissile materials worldwide in a safe, secure, transparent, and irreversible manner.

NS6: Ensure that the Department's nuclear weapons materials, facilities, and information assets are secure through effective safeguards and security policy, implementation, and oversight.

NS6-1: Providing intelligence and counterintelligence.
NS6-2: Providing security and emergency operations.

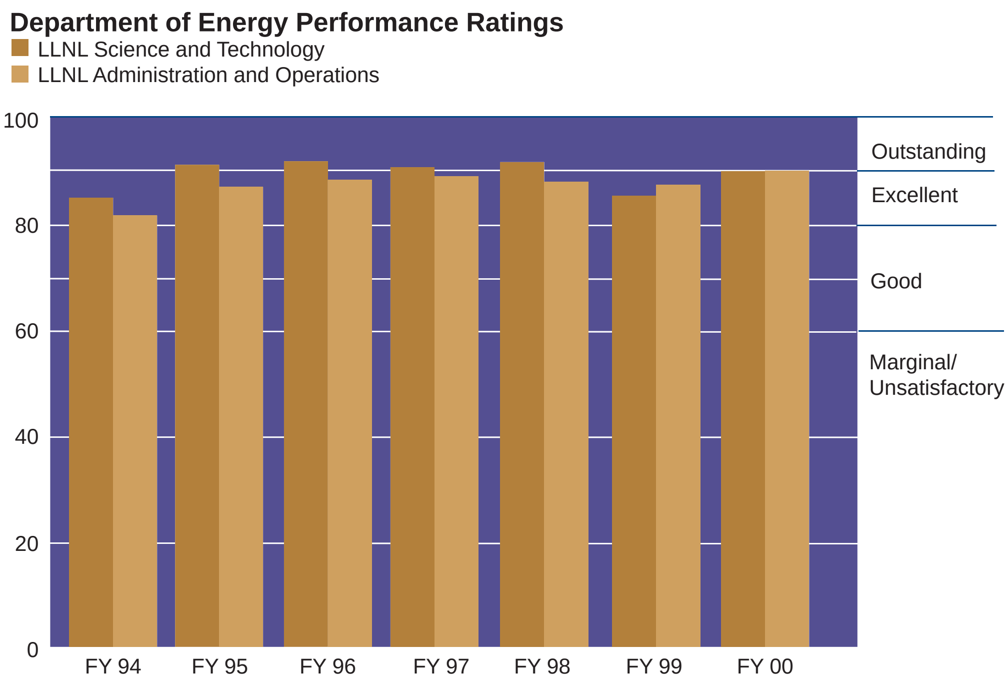


Figure 1-9. Overall, Livermore's Science and Technology (S&T) and Administration and Operations (A&O) were deemed "excellent" as measured by performance criteria defined in the performance-based management contract between the Department of Energy and the University of California.

operations and safety at the laboratories for both nuclear and nonnuclear facilities.

• Critical Skills, Knowledge and Technical Capabilities—to ensure that workforce critical skill replenishment is managed in a sound and systematic manner so that future mission needs of the Nuclear Weapons Program are effectively met.

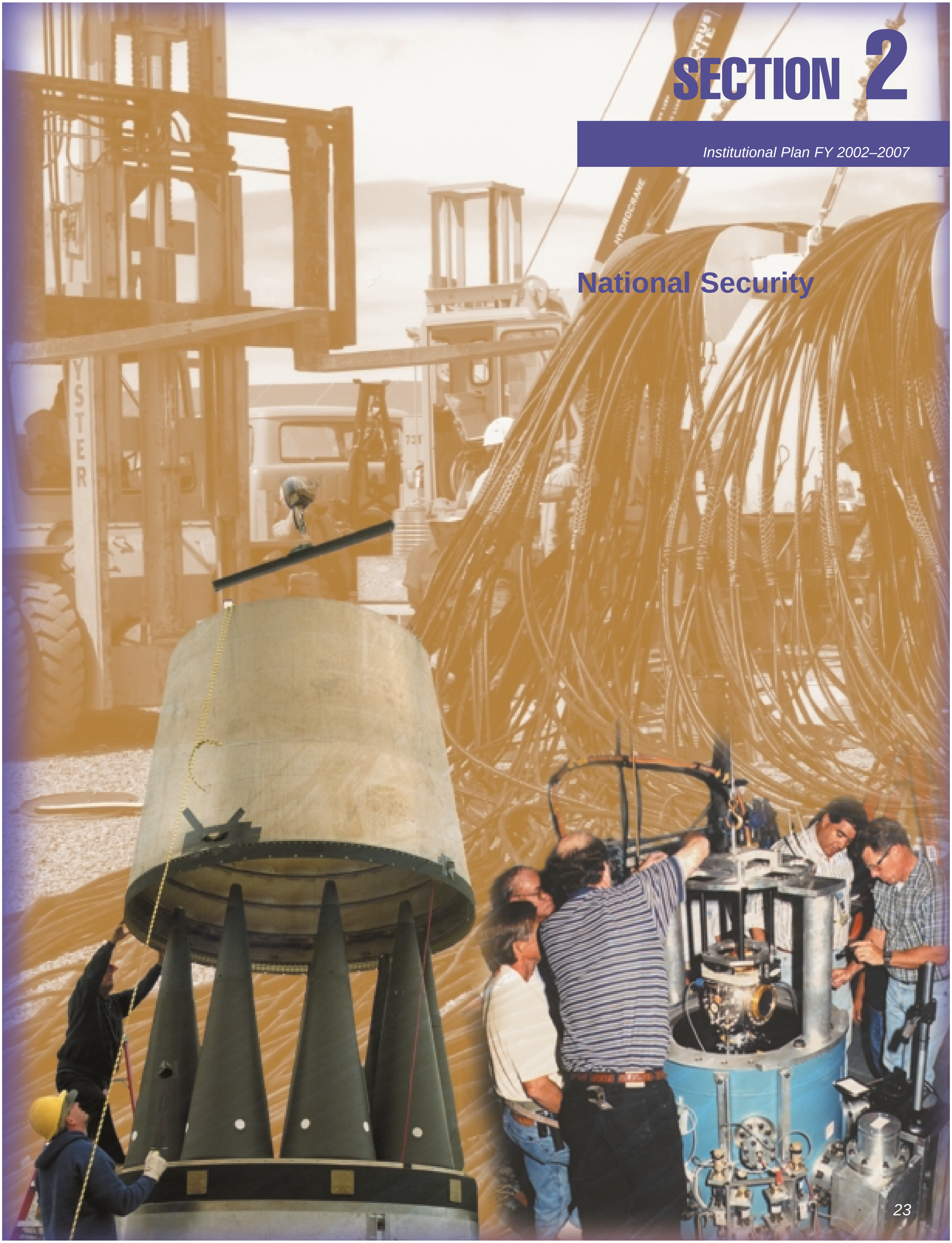
• Project Management and Construction Project Management—to strengthen project management and to institutionalize and standardize processes.

Successful implementation of Appendix O has the highest management attention at Livermore, and progress on Livermore Appendix O deliverables is proceeding on schedule. The Laboratory director has established the Contract Implementation Steering Committee (CISC) to develop and execute the Laboratory's role in working with the UC Office of the President (UCOP) to implement the restructured contract. The steering committee includes both Laboratory deputy directors, the Laboratory executive officer, five associate directors that have principal responsibilities for the initiatives, and the Laboratory's director for contract management. Particular responsibilities of the steering committee include establishing a process to implement the modified contract, collaborating and coordinating with UCOP (especially with the newly appointed UC Vice President for Laboratory Management, John McTague) and Los Alamos; and overseeing appropriate points-of-contact with UC, Los Alamos, NNSA/Oakland Operations Office (OAK), and NNSA.

SECTION 2

Institutional Plan FY 2002–2007

National Security



LAWRENCE Livermore National Laboratory was founded in 1952 as a nuclear weapons laboratory. National security remains Livermore's defining mission. The world has undergone significant changes since then, and likewise, our mission has become more dynamic and complex.

National security rests on the twin pillars of deterring aggression against the U.S. and its allies—through diplomacy, treaties, and military strength—and reducing the threats posed by others—by stemming the spread and countering the use of weapons of mass destruction. Both pillars are founded on the bedrock of U.S. scientific and technological superiority. The Laboratory's national security programs, conducted in the context of the overall national and global security environment, provide science and technology to underpin and support U.S. national security policy.

The Laboratory's national security programs align directly with the National Security Business Line General Goal in the *DOE Strategic Plan* to "enhance the national security through the military application of nuclear technology and reduce the global danger from weapons of mass destruction."

Livermore is one of the three DOE national security laboratories that are part of the National Nuclear Security Administration (NNSA) within the Department. Created through Congressional legislation enacted in 1999, NNSA brings together DOE's national security functions. The agency is responsible for long-range planning and developing comprehensive five-year budget plans for national security activities, and it manages both programmatic and operational activities within DOE/NNSA's nuclear weapons complex.

Stockpile Stewardship

Nuclear deterrence remains a key component of U.S. national security policy for the foreseeable future, and the maintenance of a safe and reliable nuclear stockpile is a supreme national interest. An early action undertaken by the new Administration was a broad review of the U.S. military for the 21st century, including a high-level review of the role of nuclear weapons and nuclear force requirements. The results of the reviews will affect NNSA's five-year planning for resource, workforce, and facility requirements at its laboratories and production facilities.

Livermore plays a key role in the Stockpile Stewardship Program for maintaining the nation's nuclear weapons stockpile in the absence of nuclear testing. The program consists of an integrated set of activities that provide surveillance of the stockpile, assessment and certification of weapon performance, and refurbishment of weapons as necessary.

The challenges that the Stockpile Stewardship Program faces will become more difficult as weapons continue to age. Bringing into operation new experimental facilities and accelerating and improving capabilities for high-performance computing with advanced simulation tools are fundamental to the success of the effort. Success also critically depends on maintaining expert judgment about nuclear weapons. We must pay particular attention to workforce recruiting, effective on-the-job training, and retention of highly qualified scientific and technical personnel to meet these challenges.

Nonproliferation and Threat Reduction

National security is threatened by the spread and potential use of nuclear, chemical, and biological weapons (collectively referred to as weapons of mass destruction, or WMD). The events of September 11, 2001, make clear the vulnerability of free societies to devastation as a result of the concerted efforts of extremists. There is heightened concern about the possible acquisition and use of WMD by the followers of Osama bin Laden. In addition, at least 20 countries, some of them hostile to U.S. interests, are suspected of or known to be developing WMD.

Improved scientific and technical capabilities are essential for WMD threat reduction. NNSA's Office of Defense Nuclear Nonproliferation supports the bulk of the research and development activities that provide the technological base for those U.S. agencies with operational responsibility for characterizing foreign weapons programs and detecting proliferation-related activities, for detecting and mitigating the use of weapons of mass destruction against U.S. civilians, and for negotiating and monitoring compliance with arms reduction and other agreements. A number of ongoing efforts at the Laboratory are directly contributing to the war against terrorism.

We are also a major player in the U.S.–Russian nonproliferation programs. These programs consist of an integrated set of activities to secure at-risk nuclear material in Russia, dispose of excess highly enriched uranium and plutonium, and assist in downsizing the Russian nuclear weapons complex by helping the Russian closed cities and weapons institutes develop self-sustaining commercial applications of their scientific and technical expertise.

Other Important National Security Needs

Building on the scientific and technical capabilities needed for the Laboratory's stockpile stewardship and nonproliferation missions, we develop advanced technologies for homeland protection and for the Department of Defense (DoD) to enhance the effectiveness of U.S. military forces. In addition to our WMD threat-reduction and threat-response work, we provide expertise in such areas as solid-state lasers, advanced conventional munitions, and energetic materials. Livermore technologies are also being applied to domestic national security issues including critical infrastructure protection, law enforcement, and counterterrorism. National laboratories such as Livermore can make valuable contributions helping the nation to anticipate and respond to long-standing, newly arising, and potential future threats to U.S. national security.

Teamwork and Advances in Science and Technology

As a Collaborative Effort. Our work takes place within the context of the national security community—the three DOE national security laboratories, the production facilities and the Nevada Test Site, DoD, and the U.S. intelligence community. Many of our projects involve extensive collaborations with other national laboratories, government agencies, universities, and U.S. industry. We coordinate and integrate our efforts with others to provide the best scientific and technical capabilities to the nation as cost effectively as possible.

Bolstered by Internal Investments. As mentioned, advances in science and technology provide the foundation for national security work. We target Laboratory Directed Research and Development (LDRD) investments to enhance our ability to meet challenging, long-term national security mission objectives and other national priorities. These investments reinforce our core strengths, expand the Laboratory's scientific and technical horizons, and create new capabilities, such as technologies for remote sensing and detection. Nearly 90 percent of the Laboratory's LDRD projects contribute to our national security mission. Livermore's overall LDRD Program is discussed in more detail in Section 3.3.2.

2.1 Stockpile Stewardship

The Stockpile Stewardship Program is designed to ensure the safety, security, and reliability of the U.S. nuclear weapon stockpile that is required to meet national security needs of the 21st century. The Office of Defense Programs within NNSA (NNSA/DP) is leading the three national security laboratories, the Nevada Test Site, and the production facilities that are part of the NNSA weapons complex in executing the program. Policy, planning, and implementation documents provide direction for the Stockpile Stewardship Program.

Stockpile stewardship is a very demanding program to meet a vital national interest. Confidence in the safety, security, and reliability of the weapons is to be maintained through an ongoing and integrated process of stockpile surveillance, assessment and certification, and refurbishment. The Stockpile Stewardship Program's ambitious goals include having in place within about a decade a set of vastly improved scientific tools and manufacturing capabilities: 100-teraops supercomputers; advanced radiography capabilities to take three-dimensional images of imploding mock primaries; a high-energy-density research facility, the National Ignition Facility, for studying the thermonuclear physics of primaries and secondaries; and efficient, flexible, and modern manufacturing facilities. Concurrently, the program must meet the current needs of DoD for direct stockpile support, which are growing as weapons continue to age.

Program Priorities and Activities at Livermore

Livermore's efforts support the three objectives identified in the *DOE Strategic Plan*'s National Nuclear Security Business Line that are related to stockpile stewardship:

Objective 1: Maintain and refurbish nuclear weapons in accordance with directed schedules to sustain confidence in their safety, security, and reliability, indefinitely, under the nuclear testing moratorium and arms reduction treaties.

Objective 2: Achieve the robust and vital scientific, engineering, and manufacturing capability that is needed for current and future certification of the nuclear weapons stockpile and the manufacture of nuclear weapon components under the nuclear testing moratorium.

Objective 3: Ensure the vitality and readiness of DOE's national nuclear security enterprise.

To meet these objectives, the Stockpile Stewardship Program is organized into three focus areas: Directed Stockpile Work, Campaigns, and Readiness in Technical Base and Facilities. These focus areas, which follow in greater detail, provide an organizational structure for Livermore's stockpile stewardship activities. Priorities for these activities are established through consideration of integrated program goals—both priorities published in stockpile stewardship policy, planning, and implementation documents and risks to the overall program if specific activities are less than fully supported.

Livermore's integrated priorities, highest first, are to:

• **Keep the current stockpile safe, secure, and reliable.** This effort involves projects such as the W87 and W80 Life-Extension Programs, surveillance, and baselining of the current stockpile systems to support Annual Certification and the planning for future life-extension programs (LEPs). These activities make full use of advanced computing capabilities and simulation tools, physical databases, and experiments at the DOE weapons complex's current suite of facilities.

• **Accelerate development of the advanced experimental and computational capabilities** needed to resolve complex stockpile issues. Major activities include Laboratory, industry, and university efforts to develop high-performance computing platforms and applications (Accelerated Strategic Computing Initiative), construction of the National Ignition Facility, and development of advanced radiography technologies and facilities that conduct high-explosive experiments on mock weapon primaries.

• **Further develop the underlying science and technology** critical to future stockpile assessment and certification. To understand the performance and aging characteristics of nuclear weapons, we need state-of-the-art theory, modeling, and experiments on materials and detailed atomic and nuclear processes.

• **Develop production technologies** for use when the current stockpiled systems must be refurbished or replaced.

Our success in meeting these priorities—particularly in the long term—depends on continuing to attract high-quality personnel in the program. Hence, an overarching Laboratory priority is to:

• **Retain, recruit, and develop the skills of the technical staff** required to execute the Stockpile Stewardship Program at the Laboratory.

The Growing Challenge

Significant challenges lie ahead because the demands on the program will grow as weapons in the enduring stockpile continue to age. Weapons in the U.S. nuclear stockpile are now older on average than they have ever been. Stockpile problems must be anticipated or detected and then evaluated and resolved without nuclear testing. Existing warheads and weapon systems will have to be refurbished to extend stockpile lifetimes and to meet future military requirements. At the same time, the reservoir of nuclear test and design experience at the laboratories continues to diminish as staff retire. This experience base—and the emerging new tools needed to resolve stockpile issues—must be passed on to the next generation of stockpile stewards.

Successful execution of Livermore's program responsibilities presents many technical and management challenges. The technical demands of the program are significant—many aspects of the required science and technology are at the leading edge of what is possible. Stockpile stewardship requires major investments in new facilities and capabilities to make it possible for scientists and engineers to understand much more thoroughly the performance of nuclear weapons. The program will not succeed without the new-facility investments that NNSA is making. At the same time, scheduled programmatic work at the laboratories and plants to meet DoD requirements is also placing exceedingly high demands on the provided funding. In addition, funds are needed to recapitalize NNSA's underlying infrastructure. Management challenges stem from the need to both integrate and balance these elements of the program while working within tight budget constraints.

Managers are also responsible for ensuring that expertise remains high in all aspects of nuclear weapon science and engineering, with particular attention to workforce recruiting, effective on-the-job training, and retention of highly qualified scientific and technical personnel. Workforce recruiting and development are high priorities at the Laboratory (see Section 4.3). Both recruiting and retention of top-quality staff benefit from the Laboratory's LDRD Program (Section 3.3.2) and various ties to universities (Section 3.4.3). These efforts, together with the Science and Technology Education Program (Section 3.4.4), help to attract high-caliber scientists and engineers and develop a future workforce to work on challenging national security problems.

2.1.1 Integrated Program Management and Implementation

Situation and Issues

Integrated program management and implementation are critical to the success of the Stockpile Stewardship Program. The major program elements are tightly interconnected, as are the activities of the three laboratories, the production facilities, and the Nevada Test Site. Policy, planning, and implementation documents developed by NNSA specify roles and responsibilities within the program and define the capabilities needed for stockpile stewardship without nuclear testing. The plans integrate surveillance, assessment, and life-extension design and manufacturing activities for each weapon system, and (to the extent possible) time-phases all activities to balance the workload. Program integration efforts also include formal processes with DoD for coordinating assessments of stockpile performance and modifications.

Program Thrusts

Annual Assessment and Independent Reviews. Livermore is a key participant in formal review processes and assessments of weapon safety, security, and reliability. Annual Certification of the stockpile for the President (now called the Annual Assessment Review) is a formal process that is based on technical evaluations made by the laboratories and on advice from the three laboratory directors, the commander-in-chief of the Strategic Command, and the Nuclear Weapons Council. To prepare for this process, we collect, review, and integrate all available information about each stockpile weapon system, including physics, engineering, chemistry, and materials science data. This work is subjected to rigorous, in-depth intralaboratory review and to expert external review.

In addition to Annual Assessment Review, Livermore contributes to a variety of independent reviews of weapons systems. In the absence of nuclear testing, the nation increasingly must rely on independent assessments by the NNSA laboratories to ensure the safety, security, and reliability of weapons in the stockpile. For example, NNSA/DP recently concluded a Dual Revalidation of the W76, in which the SLBM warhead design was examined in detail over a three-year period. The dual revalidation consisted of assessments by Los Alamos, which designed the warhead, and Livermore, which pursued extensive experimental and computational work to evaluate W76 performance. In the future, the laboratories will be conducting a set of less comprehensive baselining studies to archive and update technical analysis of each system over a five-year period.

Program Alignment and Integration. For the Stockpile Stewardship Program to succeed, it is crucial that the activities at the three laboratories, the Nevada Test Site, and the production facilities be a unified effort with integrated goals, milestones, and schedules. To this end, the program is formally managed through three overarching sets of activities: Directed Stockpile Work, Campaigns, and Readiness in Technical Base and Facilities. NNSA/DP uses this breakout to make evident program integration, establish clear program goals and budget priorities, and help to identify program risks if there are budget shortfalls. The integrated program activities include:

• **Directed Stockpile Work.** Directed Stockpile Work supports the readiness of weapons and includes activities to meet current stockpile requirements. It involves production activities and research and development that directly apply scientific understanding and engineering capabilities to the assessment, refurbishment, and certification of the weapons stockpile. The effort includes weapon maintenance, comprehensive surveillance, weapon baselining, assessment and certification, supporting research and development, and scheduled weapon refurbishments. It also includes other stockpile commitments, such as dismantlement and information archiving.

• **Campaigns.** Campaigns are directed at making the scientific and technological advances necessary to assess and certify weapon performance now and over the long term without nuclear testing. Campaigns are focused, technically challenging, multifunctional efforts that address critical capabilities needed to achieve certification of stockpiled weapons. They develop and maintain specific critical capabilities that are needed to sustain a viable nuclear deterrent. Each campaign has milestones and specific end dates designed to focus advanced basic and applied science, computing, and engineering efforts on well-defined deliverables related to the stockpile. The current set of seventeen campaigns—eleven of which focus on scientific activities at the three laboratories—provides a planning framework for the program's research and development activities.

• **Readiness in Technical Base and Facilities.** Readiness in Technical Base and Facilities ensures that necessary investments are made to conduct the program today and to have in place the needed capabilities as more challenging stockpile issues arise in the future. Readiness includes the fixed costs and the investments of the Stockpile Stewardship Program. Readiness depends on (1) exceptional, motivated people in the program with the needed skills and training; (2) a well-maintained, modern infrastructure to support the activities of these people and to operate in a safe, secure, and environmentally responsible manner; and (3) special experimental and computational facilities for future stewardship activities in the absence of nuclear testing.

In conjunction with this approach to managing program activities, a rigorous planning process has been established to clearly define programmatic milestones to be achieved within each program element. The Stockpile Stewardship Program is defined by a series of five-year plans, one for each program element, describing goals and objectives. The five-year plans—developed with the participation of the laboratories, plants, and test sites—are accompanied by annual implementation plans with detailed milestones.

2.1.2 Directed Stockpile Work

Directed Stockpile Work supports the readiness of weapons. It includes weapon maintenance, comprehensive surveillance, weapon baselining, assessment and certification, supporting research and development, and scheduled weapon refurbishments. The effort also includes other stockpile commitments, such as dismantlement and information archiving.

Situation and Issues

Stockpile Requirements. On an annual basis, the President issues the Nuclear Weapons Stockpile Plan, which is first prepared by the Nuclear Weapons Council and reviewed by the Secretaries of Defense and Energy. The plan sets the requirement to maintain a safe and reliable nuclear weapons stockpile. It specifies the number of weapons of each type to be in the stockpile and, hence, which nuclear weapons systems are available for dismantlement. Among its other responsibilities, DoD establishes military requirements, which are incorporated into the President's plan. These requirements drive the Directed Stockpile Work for NNSA, particularly in the resource-intensive area of refurbishment activities and LEPs.

Livermore-Designed Weapons and Responsibilities. Livermore is the design laboratory for four nuclear weapon systems in the stockpile: the W87 and W62 ICBM warheads, the B83 bomb, and the W84 cruise missile warhead. These systems are expected to remain in the stockpile well past their originally anticipated lifetimes; the W62 is already doing that. The Laboratory has special responsibilities for these systems, including surveillance, performance and safety assessments, and refurbishment.

Certification of the life-extension refurbishment of the W87 ICBM warhead has been completed. In April 2001, Admiral Richard Mies (commander-in-chief of U.S. Strategic Command) and General Gordon signed the Final Weapon Development Report. This first completed certification of the engineering design and production processes for an LEP is a groundbreaking milestone for the Stockpile Stewardship Program. Production of refurbished W87 warheads is now in progress, and we are developing additional LEPs to extend the stockpile life of the other Livermore-designed systems.

Lawrence Livermore and Sandia/ California have also been assigned responsibility for the program to extend the life of the W80 cruise missile warhead. In addition, the Laboratory has broader responsibilities to develop assessment capabilities, technologies, and processes that contribute to maintaining the safety, security, and reliability of all stockpiled weapons.

Assessments. Assessments provide the foundation for formal certification of stockpile performance and for refurbishment decisions. Assessments must be based on scientific and engineering demonstrations to be credible. In the absence of nuclear testing, we rely on data from past nuclear tests as a benchmark, component-level experiments and demonstrations, and advanced simulations for an integrated assessment of weapon performance and safety.

The Stockpile Stewardship Program includes a comprehensive set of assessment activities to address issues that arise from stockpile surveillance and to evaluate the significance of observed and predicted aging processes. When modifications are deemed necessary, we must assess options for refurbishing or replacing specific warhead components as well as options for new production and fabrication processes and materials. Modification actions must then be certified.

Stockpile Surveillance. Our stockpile surveillance activities focus on Livermore designs in the stockpile. These efforts include developing improved monitoring capabilities and building the scientific base to better understand aging effects in all stockpiled weapons (see Enhanced Surveillance Campaign in Section 2.1.3). With a better understanding of aging, we can better predict changes in the stockpile and conduct systematic refurbishment and preventive maintenance activities to correct developing problems. We also perform surveillance testing of the detonator systems on the Livermore-designed weapons. In addition, pits from Livermore-designed weapons will now be thoroughly examined at facilities in the Superblock—a new mission for Livermore. These stockpile surveillance activities previously had been conducted at Los Alamos.

Weapon Refurbishment. Weapon refurbishment—needed because weapon components degrade over time—is a particularly demanding challenge because we cannot rebuild many weapons components exactly as they were manufactured. In many cases, the materials or the manufacturing processes originally used are no longer available or are environmentally unacceptable.

Activities to improve the manufacturing of weapons components are part of LEPs as well as the Advanced Design and Production Technologies

(ADaPT) Campaign discussed in Section 2.1.3. We are working closely with the production plants to integrate the development of replacement components with the development of new materials and manufacturing processes. By making use of modern production technologies and incorporating major technical advances that have occurred since the weapons were first manufactured, we can lower the cost of weapon refurbishment and reduce the environmental impact.

Program Thrusts

A Strategy to Improve Assessment Capabilities. The expectation that more challenging stockpile issues will arise as weapons continue to age is driving the program's campaign strategy (see Section 2.1.3) and investments in more capable experimental facilities (see Section 2.1.4). These investments include the National Ignition Facility (NIF) and the Dual Axis Radiographic Hydrodynamic Test (DARHT) Facility at Los Alamos. We are also developing greatly enhanced numerical simulation tools through the Accelerated Strategic Computing Initiative (ASCI). Livermore has major responsibilities in the execution of ASCI and the construction and eventual operation of NIF.

W87 Life Extension. A principal program thrust at Livermore has been the W87 LEP. In April 2001, General John Gordon, NNSA administrator, and Admiral Richard Mies, commander-in-chief of U.S. Strategic Command participated in a ceremony at Livermore in recognition of the signing of the W87 LEP Final Development Report by the directors of Livermore and Sandia. The W87 LEP is a success story—we achieved all planned major milestones. This first completed warhead certification, which incorporated the engineering design and production processes for an LEP, was a groundbreaking milestone for the Stockpile Stewardship Program. It demonstrates the laboratories and production facilities working together to overcome physics, engineering, and manufacturing challenges to meet DoD requirements.

The objective of the LEP is to enhance the integrity of the warhead so that it can remain part of the enduring stockpile beyond the year 2025 and will meet anticipated future requirements for the system. The development activities included extensive flight testing, ground testing, and physics and engineering analysis. The first refurbished unit was completed in February 1999, and the final production unit is scheduled for completion in 2004.

W80 Life Extension. Under the direction of the Nuclear Weapons Council, the W80 Project Officers Group (POG) is pursuing an LEP for the W80 cruise missile warhead. A formal study that defined refurbishment options and their feasibility (known as a 6.2 study) was completed in 2000. Livermore and Sandia/California participated as an Interlaboratory Peer Review team. Although the W80 was originally developed by Los Alamos and Sandia/New Mexico, NNSA assigned the associated engineering development task for the LEP to Livermore and Sandia/California. Working closely together, the New Mexico and California teams established a modern baseline understanding of the W80 and its performance.

The recommended refurbishment option for the LEP was selected by the W80 PO. The schedule calls for the first production unit of the refurbished warheads in FY 2006. Livermore will be responsible for continuing evaluations of their performance. Los Alamos will retain this responsibility for W80s not yet refurbished.

Improved Surveillance of the Stockpile. Using the experience and data we have gathered, we continually review and upgrade our surveillance programs—refining sampling plans, measuring additional attributes, introducing new diagnostic tools, and improving analysis methods. We are also taking on responsibility for surveillance of pits from Livermore-designed weapons in the stockpile to better balance the workload. These activities had been conducted at Los Alamos.

In addition, as our contribution to the Enhanced Surveillance Campaign (see Section 2.1.3), we are improving the sensors and techniques used to inspect weapons. For example, Livermore has completed development of a solid-phase, micro-extraction diagnostic to detect and characterize the presence of minute quantities of chemicals in warheads. The system is now deployed at Pantex. We are also completing development of high-resolution x-ray tomography for imaging weapon pits, and deployment at Pantex is in progress. Furthermore, development continues of high-energy neutron radiography for nondestructively detecting small voids and structural defects in weapon systems. Working with Y-12, AlliedSignal, and Savannah River, we are also pursuing micro-sensors for evaluation of materials degradation and corrosion in weapon systems.

Improved Production Technologies. We are developing a complex-wide, secure, high-speed digital network. In effect, it is serving as a "Secure Internet" with classified information shared on a need-to-know basis throughout the weapons complex. Initial implementation of the system is enabling Livermore engineers and designers to have access to "as-built" production, disassembly, and surveillance data from Y-12 and Pantex during W87 LEP activities. The Weapons Technical Data Exchange project is also supporting the W80 LEP through the transfer of data for the W80 warhead system between Los Alamos, which designed the W80, and Livermore, which is responsible for the LEP.

Other information and manufacturing technologies are being pursued as part of Livermore's contribution to the ADaPT Campaign in projects designed to support plans and needs for stockpile LEPs. Activities range from the development of precision die-casting technologies for pit production and new methods for production of TATB (insensitive high explosives) to tomographic diagnostic techniques for electron-beam welding.

Directed Stockpile Workload Planning. Building on the success of the W87 LEP, we are developing comprehensive plans to extend the stockpile life of other Livermore-designed systems. To this end, significant effort is being expended on their surveillance, maintenance, and selective refurbishment.

DOE and DoD must work together effectively to refine work plans—including budgets and schedules—for future refurbishment activities for each system in the enduring stockpile. We need to develop a range of realistic, well-defined options that then must be weighed according to risks and benefits. Balancing benefits and risks in a highly constrained budget environment will be difficult. Near-term affordability issues—together with the prospect of better definition of which components should be replaced and the possibility for improved design options—argue for tackling the more challenging refurbishment actions later if they are not yet necessary. However, that decision could lead to later workload balancing issues at the plants. It would also increase the burden on future stockpile stewards, who will face the more challenging issues without the experience base of the current staff.

2.1.3 Stockpile Stewardship Campaigns

Situation and Issues

The Stockpile Stewardship Program Campaigns are directed at making the scientific and technological advances necessary to assess and certify nuclear weapon performance now and over the long term. They integrate experiments, simulation development, and assessment activities and focus on achieving specific needed capabilities. Seventeen campaigns are being pursued.

Each campaign has a specific end date and is designed to achieve a quantifiable end state associated with a specific stockpile stewardship goal. As they progress, the campaigns will achieve scheduled interim objectives relevant to stockpile needs. For each campaign, the resource needs have been determined together with an assessment of program risks if funding is not adequate. In addition, a set of cross connections with other elements of the program has been identified.

Significant Accomplishments. In FY 2000 and FY 2001, Livermore achieved a number of significant accomplishments in its campaign activities, such as:

- The first-ever three-dimensional (3D) simulation of a nuclear weapon primary explosion, completed in December 1999, and significant progress on the 3D simulation of a nuclear weapon secondary (successfully completed in June 2001).
- Continuing success in the Oboe subcritical experiments, which use confinement vessels for rapid turnaround of test results.
- Progress in understanding the aging of key materials in weapons through a variety of laboratory experiments and modeling efforts.
- Experiments using the Omega laser yielding data for the comparison of radiation transport models as well as thorough examination of the types of high-energy-density physics experiments that could be conducted using the National Ignition Facility.

These and other accomplishments are described in more detail in Livermore's *Annual Report*, *Science & Technology Review* (the Laboratory's monthly publication), and *National Security Review* (the Laboratory's classified journal).

Program Thrusts

The current set of 17 campaigns is briefly described. Teams from across the DOE weapons complex work together to focus and optimize their combined resources to achieve overall milestones and end states. Livermore's role in each campaign varies, and our major contributions are highlighted in Table 2-1.

In general, we are primarily focused on the eight campaigns to improve the scientific understanding of weapons performance. We also work in close partnership with the production facilities on the three applied-science and weapons-engineering campaigns, and in selected areas, we provide development support to the six campaigns to sustain the manufacturing base.

Eight campaigns are aimed at providing the scientific understanding needed to certify the nuclear weapons stockpile in the absence of nuclear testing and to support required weapon modernization in LEPs. The additional campaigns focus on applied science and

Table 2-1. Livermore contributions to the DOE/NNSA Defense Program Campaigns.

Campaign	Major Livermore Technical Efforts
1. Primary Certification	High-fidelity modeling and experiments: with plutonium at NTS (JASPER gas gun and subcriticals), high explosives at the High-Explosives Applications Facility (HEAF) and Site 300, hydrotests at the Flash X-Ray/Contained Firing Facility and DARHT; calculational model development.
2. Dynamic Materials	Subcritical and gas-gun experiments (Pu); high-explosive experiments at HEAF and Site 300; NIF experiments Properties (deuterium and tritium equation of state); model development.
3. Advanced Radiography	Linear induction accelerator (LIA) work for DARHT-2; lead for LIA technology demonstration facility; materials research.
4. Secondary Certification & Nuclear Systems Margins	Opacity, transport, and interaction experiments at Omega and NIF; physics model development.
5. Enhanced Surety	Development of advanced initiation, safing, optical, and high-explosives technologies.
6. Weapon System Engineering Certification	Experiments to validate models; system-level confirmatory experiments.
7. Certification in Hostile Environments	Nuclear weapon outputs and environments; weapon vulnerability and hardness, including experiments at Omega and NIF.
8. Enhanced Surveillance	Aging (and accelerated aging) of pits, canned subassemblies, and high explosives; laboratory experiments;modeling.
9. Advanced Design & Production Technologies	Development of materials and production process technologies.
10. ICF Ignition & High Yield	NIF construction and operation; target design and fabrication; experiments and diagnostics.
11. Advanced Simulation & Computing	ASCI applications development; data visualization; platform integration; validation and verification.
12–17. Production Readiness Campaigns	Development of production processes.

weapons engineering. They provide specific tools, capabilities, and components to support weapon maintenance, modernization, and refurbishment as well as certification of weapon systems. The 11 campaigns are:

1. Primary Certification Campaign. This campaign focuses on developing and implementing the tools required to certify the performance and safety of any rebuilt or aged primary. Primary performance must be understood within a certain margin of error. Among the many activities supporting this campaign are efforts to develop validated models of high-explosives denotation, boost physics, and primary burn.

2. Dynamic Materials Properties Campaign. The goal of this campaign is to develop data and accurate, experimentally validated models that describe the behavior of materials at the level of accuracy needed for certification of weapon performance. One area of special emphasis is determination of the equation of state and constitutive properties of plutonium (e.g., strength, spall, ejecta) as well as organic materials and deuterium–tritium gas mixtures.

3. Advanced Radiography Campaign. This campaign aims to provide three-dimensional dynamic radiographic images of imploding surrogate primaries as well as associated analytical capability applicable to the certification of rebuilt primaries. After nuclear testing, advanced radiography is the most important experimental tool that we have to maintain an aging nuclear stockpile. This campaign includes completing and operating the DARHT Facility, developing advanced simulation and analysis capabilities, and providing a technical basis for deciding the next step on the path to more advanced radiography capabilities.

4. Secondary Certification and Nuclear Systems Margins Campaign. This campaign examines the performance of secondaries to identify the minimum factors necessary to produce a militarily effective weapon. The objectives of this campaign include (1) developing a validated predictive computational capability for each system in the stockpile; (2) quantifying, through simulation and experiments, our understanding of primary radiation emission and energy flow; and (3) determining the performance of nominal, aged, and rebuilt secondaries. In the past, our less-than-complete understanding of these issues required nuclear tests to establish performance "margins." Without such tests, aging and remanufacturing issues require a more rigorous predictive capability.

5. Enhanced Surety Campaign. The goal of this campaign is to increase nuclear safety and security. Main efforts include developing advanced capabilities in micro, optical, and solid-state technologies that improve nuclear warhead safety, as well as enhancing use-control and use-denial technologies. A critical factor is to qualify surety solutions for planned stockpile life-extension refurbishment activities while maintaining flexibility to respond to surprises encountered during refurbishment.

6. Weapon System Engineering Certification Campaign. The intent of this campaign is to establish engineering certification methods that quantify performance and uncertainties of weapon systems at a reduced cost. Predictive engineering computational models for stockpile LEP activities will be developed and validated through fewer, smarter, system-level confirmatory experiments. The goal is to greatly increase the information gained from each fielded experiment so that we can increase weapons understanding while we reduce the number of tests and associated costs.

7. Certification in Hostile Environments Campaign. The goal of this campaign is to develop certification tools and microelectronics technologies to ensure that refurbished weapons meet stockpile-to-target-sequence (STS) requirements for hostile environments. Technical objectives include developing a suite of validated computational tools for radiation-hardened design and certification using nuclear environments generated with pulsed-power and laser-based facilities, reevaluating nuclear-weapon hostile environments, and demonstrating certification technologies on the W76 LEP. The development of computational models will reduce reliance on laboratory tests.

8. Enhanced Surveillance Campaign. This campaign will provide a validated basis to certify aged components, specify when components must be replaced, and determine when new manufacturing facilities are needed. It will provide the first science-based assessment of the lifetimes of pits, high explosives, organic materials, and canned secondary subassemblies and furnish quantitative bases for future stockpile life-extension activities. One of the goals is to minimize or eliminate unnecessary refurbishment costs.

9. Advanced Design and Production Technologies (ADaPT) Campaign. This campaign aims to develop improved modeling and simulation tools and information management technologies so that refurbishment products are high in quality and are delivered cheaply and quickly. The campaign will enable full-scale engineering development for weapon component refurbishment with minimal hardware prototyping and paperless monitoring of production activities.

10. Inertial Confinement Fusion (ICF) Ignition and High-Yield Campaign. The long-term goal of this campaign is to achieve ICF ignition implosions in the National Ignition Facility (NIF). Material conditions that can be reached in NIF, together with the diagnostics available, will allow the experimental study of thermonuclear burn and important regimes of high-energy-density science. Understanding physical phenomena at starlike temperatures and pressures is critical to understanding how nuclear weapons work.

11. Advanced Simulation and Computing Campaign. This campaign focuses on the shift from nuclear-test-based methods to computation-based methods to certify the safety, reliability, and security of the stockpile. The capabilities coming online through ASCI make possible three-dimensional, high-fidelity, full-system simulations. The goal is to develop the simulation software required for engineering, safety, and performance analyses of weapons in the stockpile.

The final six campaigns support readiness by focusing on sustaining the manufacturing base within the weapons complex.

Pit Manufacturing Readiness Campaign. The goal of this campaign is to reconstitute pit manufacturing within the DOE nuclear weapons complex, including the reestablishment of the technical capability to manufacture pits for the enduring stockpile at a capacity of 20 pits per year.
Secondary Readiness Campaign. This campaign will ensure that future manufacturing capabilities are in place, including the reestablishment of special materials processing, replacement of antiquated technologies, maintenance of workforce competencies, and development of component certification and recertification techniques for weapon secondaries.
High-Explosives (HE) Manufacturing and Weapon Assembly/Disassembly Readiness Campaign. This campaign is focused on ensuring future manufacturing capabilities for high-explosives fabrication and weapon assembly.
Nonnuclear Readiness Campaign. This campaign will ensure that future manufacturing capabilities for nonnuclear components are available.
Materials Readiness Campaign. This campaign includes activities to support the construction of a new highly enriched uranium (HEU) storage facility at Y-12.
Tritium Readiness Campaign. The focus of this campaign is to develop a source of tritium for meeting future stockpile needs. A commercial light-water reactor is the primary technology option under consideration, with a linear accelerator (linac) option as a backup.

2.1.4 Readiness in Technical Base and Facilities

Readiness in Technical Base and Facilities calls for investments in people and their supporting infrastructure to conduct the program today and to have in place the needed capabilities as more challenging stockpile issues arise in the future. The Stockpile Stewardship Program's success depends on the presence of well-trained, motivated people together with a well-maintained, modern infrastructure that is operated in a safe, secure, and environmentally responsible manner.

Success also requires bringing online the special experimental and computational facilities that are especially needed in the absence of nuclear testing. Not formally part of the Readiness in Technical Base and Facilities element of the Stockpile Stewardship Program, the Laboratory's major activities in the National Ignition Facility and the Accelerated Strategic Computing Initiative are discussed in Sections 2.1.5 and 2.1.6.

Situation and Issues

A Quality Workforce. We face the absolutely crucial challenge of maintaining expert judgment about nuclear weapons issues. That challenge has been recognized from the onset of the Stockpile Stewardship Program. It was carefully considered by the Commission on Maintaining United States Nuclear Weapons Expertise ("Chiles Commission") and more recently by the Foster Panel and the National Commission on Science and Security ("Hamre Commission"). These panels noted that morale at the NNSA laboratories is low and correctly pointed out the need at the laboratories for a sustained recruiting and training effort to supplement our veteran workforce.

Retirement age is nearing for a significant fraction of the Laboratory's career workforce with "critical skills" that support the Stockpile Stewardship Program and related activities. Nearly 40 percent of Defense Programs–funded engineers, scientists, technicians, and their managers are over 50 years old. Less than 20 percent of the "critical skills" career-employee population at Livermore is 40 years old or younger. Retention of the current staff and recruitment and training of new scientists, engineers, and technicians are vitally important for the continuing health of the Stockpile Stewardship Program.
Key Stockpile Research Facilities at Livermore. Livermore has special responsibilities in the Stockpile Stewardship Program because of our special skills and capabilities and because unique user facilities at Livermore must be maintained. In addition to a number of important but smaller science and engineering facilities, these include:
- The High-Explosives Applications Facility (HEAF). The most modern facility for high-explosives research in the world, HEAF is a center for the study of chemical high explosives. It combines all the capabilities needed to synthesize, formulate, and test new explosive compounds. High explosives can be safely detonated in specially designed vessels in quantities up to 10 kilograms. Experiments are supported by state-of-the-art diagnostic equipment that includes high-speed, rotating-mirror streaking and framing cameras, electronic image-converter cameras, optical interference velocimeters, and image-forming x-ray machines.
- The Flash X-Ray/Contained Firing Facility at Site 300. This modern hydrodynamic test facility is capable of conducting "core punch" experiments that record a detailed digital image of a mock weapon primary when it is highly compressed. The Flash X-Ray Facility was shut down in 1999 and work began on an upgrade to contain the debris

created by explosive testing. Construction of the Contained Firing Facility is finished, and the facility has been undergoing qualification testing to assure its ability to contain debris from experiments that use up to 60 kilograms of high explosives. When hydrodynamic testing resumes in late 2001, Livermore will be able to conduct these critically important experiments in an even more environmentally benign manner.

• The Secure and Open Computing Facilities. These facilities assist our programs and serve as a testbed for development of high-performance computing hardware and software. Livermore Computing maintains two computing facilities, one for classified work (the Secure Computing Facility) and the other for unclassified work (the Facility for Advanced Scalable Computing Technology).

• The Superblock. Housing modern facilities for special nuclear materials research and engineering testing, the Plutonium Facility, in particular, is engaged in activities to prepare and monitor accelerated-aging plutonium samples. The facility is also used to prepare plutonium samples for Livermore's subcritical tests, to investigate technologies for the remanufacture of plutonium parts in Livermore-designed weapons, and to conduct other fundamental physics and engineering experiments using plutonium. In addition, pit surveillance of Livermore-developed weapons is now being conducted at the facility.

The Need for Infrastructure Reinvestment. We strive for a work environment at Livermore that attracts top-notch employees, enhances workforce productivity, and helps ensure programmatic success. This requires modern facilities at the Laboratory. A core strength of Livermore is its unique, state-of-the-art research facilities, but we also have many aging facilities.

As discussed in Section 4.4, overall, 14 percent of Livermore's office and laboratory space is in need of major rehabilitation and nearly 30 percent of the space is in need of minor rehabilitation. Older facilities typically are more expensive to maintain and usually have higher costs associated with safe and healthy operations. Our overall maintenance backlog is about $330 million if funded with programmatic dollars. In addition, obsolete equipment needs to be replaced. The Laboratory also has legacy facilities from long-discontinued programs as well as outdated and unusable laboratory space that must be decommissioned, decontaminated (where necessary), and demolished. Finally, we have to invest so that buildings at Livermore meet present-day codes and the latest, more demanding seismic safety criteria.

Program Thrusts

The Laboratory's future workforce and facilities are areas of considerable attention. The steps we are taking in workforce recruitment and retention are discussed in Section 4.3. Some of our activities that particularly pertain to recruiting are highlighted below. Section 4.2.1 presents a comprehensive summary of Livermore's facility plans and resource requirements. Here, we briefly discuss two major construction items.

Recruitment for Defense Programs Activities. New employees recruited into Livermore directorates that support stockpile stewardship come from a number of sources, all of which require Laboratory outreach, particularly to academic institutions. Recruitment measures include on-campus recruiting, relationships established through collaborative research activities, postdoctoral fellowship programs at the Laboratory, contacts made at professional scientific and engineering society meetings, advertisements in professional journals, and position postings on the World Wide Web. In particular, Livermore benefits from Defense Programs' Laboratory Critical Skills Development Program, which directly provides matching funds to support many interns who work on stockpile stewardship projects (see Section 3.4.4). In addition, through a variety of activities, we have developed a wide range of academic collaborations on physics and computational topics relevant to the needs of the Stockpile Stewardship Program. Two prominent examples are the University of California Research Institutes (five of which are located at Livermore, as discussed in Section 3.4.3) and the Academic Strategic Alliances Program (ASAP), which is part of ASCI. These academic alliances are discussed in Section 2.1.6. Many other Laboratory-wide efforts to bolster workforce recruiting, continuing education, and retention are discussed in Section 4.3.

Infrastructure Reinvestment. As discussed in Section 4.4, through the use of the prioritization methods and innovative rehabilitation and decontamination and demolition (D&D) processes we have piloted, the Laboratory has in place effective means for managing its infrastructure—but we do not have enough funding to make headway at reducing accumulated problems. Accordingly, our input into NNSA/DP's Infrastructure Recapitalization Initiative in November 2002 totals $65.8 million for FY 2002, with $42.2 million for high-priority items for that year. Some of the 12 high-priority maintenance, general plant projects, and capital equipment items include replacement of electrical power systems in aging facilities, a number of building renovation projects, and investments in high-efficiency particulate air (HEPA) filters to more effectively ensure that our high environmental standards continue to be met. Two other high-priority projects include a D&D project and a scoping and design study for rehabilitation of a major building complex at our site.

2.1.5 The National Ignition Facility

The National Ignition Facility (NIF), currently under construction at Livermore, will be a 192-laser-beam facility capable of achieving fusion ignition and energy gain in the laboratory for the first time. The NIF design provides 1.8 megajoules of ultraviolet laser light in 192 beams directed into a 10-meter-diameter target chamber. The NIF facility consists of a laser and target area building nearly 300,000 square feet in size with adjacent support facilities for cleaning and assembling the optical components of the laser, target diagnostics, and experimental support and a number of test facilities for integrated systems development, prototyping, and qualification.

NIF builds upon the extensive experience gained at Livermore using a series of large lasers built over the past 30 years. NIF will deliver 60 times more energy than the Nova laser, which was built and operated at the Laboratory between 1984 and 1998. Many of the key technical features of NIF were tested using the Beamlet Laser at Livermore, which operated between 1994 and 1998. Features included the multi-pass amplifiers; large-aperture optical switches; large frequency-conversion crystals; deformable mirrors for adaptive optical correction of laser beam wavefront; power conditioning, capacitor, and flashlamp systems; and high-fluence, large-area optics.

Situation and Issues

The Need for NIF. NIF will support national security, energy, and scientific goals. A critical element of the Stockpile Stewardship Program, NIF is designed to maintain the safety, security, and reliability of the country's remaining nuclear weapons without full-scale nuclear testing. It is the only facility in the program that can achieve fusion ignition and obtain temperatures and pressures approaching those in an exploding nuclear weapon. Experiments on NIF will also evaluate the scientific feasibility of inertial fusion energy, which has been a long-standing program goal within DOE. In addition, NIF will provide nuclear environments for studying weapons effects and will allow laboratory astrophysics studies under conditions similar to those found in stars.

We need the facility for experimental study of key issues related to the effect of aging on weapons and for certification of the performance of refurbished weapons. In addition, NIF experiments provide the only available means for advancing critical elements of the underlying science of nuclear weapons. NIF experiments will provide necessary data for sophisticated computer simulation models being developed for stockpile stewardship, and the models themselves need to be tested in the physical conditions that only NIF can provide. Finally, NIF will help to attract and train the exceptional scientific and technical talent that is required to sustain the Stockpile Stewardship Program over the long term.

The findings of NNSA/DP's High-Energy-Density Physics (HEDP) Workshop, held January 30–February 2, 2001, reconfirmed NIF's essential role in the Stockpile Stewardship Program and recommended that NIF be completed to its full 192-beam configuration on its baseline schedule. The workshop panel included representatives from DOE, NNSA, DoD, the three NNSA laboratories, and Argonne National Laboratory. They reviewed presentations by experts in weapons design, HEDP, and inertial confinement fusion (ICF) from the three laboratories. Topics included options for NIF deployment, other HEDP facilities that can complement NIF, and Stockpile Stewardship Program needs for HEDP, weapons experiments, and calculations for future stockpile certification.

NIF Project Status. A series of milestones has occurred on the NIF project, beginning with Key Decision Zero in January 1993, which established mission need. The most recent high-level milestone of the project was Critical Decision Three (March 1997), the approval to begin construction.

In late FY 2000, the NIF rebaselined cost and schedule were found to be acceptable and soundly based by the Level 0 Baseline Change Control Board, which is part of the Energy Systems Acquisition Advisory Board (ESAAB), chaired by the Deputy Secretary of Energy. The new NIF baseline schedule calls for first light to the target chamber in June 2004 and all 192 beams to be commissioned by September 2008. The ESAAB approval of the new NIF baseline allowed the Secretary to submit his certification of the NIF project baseline and his recommendations for FY 2001 and out-year funding plans to Congress as required. In October 2000, Congress funded the NIF project with a reduction of $10 million from the requested baseline. This reduction—along with added negative NIF project impacts of DOE-mandated security measures, ICF program recisions, and greater-than-planned inflation—has required continued analysis of project priorities and scope in an effort to accommodate these funding shortfalls without jeopardizing long-term project contingency reserves.

In February 2001, the NIF project received approval from the Level 2 Change Control Board to modify the Construction Project Data Sheet as required by the Project Execution Plan to take into account the reduced Congressional funding, a Safeguards and Security Amendment reduction, and a Consolidated Appropriations Act recision. No high-level DOE/NNSA milestones are affected, and there were no changes to the Total Project Cost. Lower-level milestones have been adjusted to allow modifications in procurements, and some funds were shifted from FY 2008 into FY 2003 to make up for the shortfall in FY 2001. The NIF project is now proceeding in a manner consistent with the needs of the overall Stockpile Stewardship Program.

Program Thrusts

Progress on Construction. Recent accomplishments in the construction of NIF include completing the Class 100 cleanliness level Optics Assembly Building and commissioning laser component manipulators and transporters; certifying both laser bays to Class 100,000 clean room conditions; substantially completing the Laser and Target Area Building (LTAB, the stadium-sized building that houses NIF's 192-beam laser system, the switchyards, and the target chamber); installing one cluster (48 beams) of amplifier housings; installing over 1,000 tons of laser beampath hardware; and completing assembly and precision alignment of the 1,000,000-pound, 10-meter-diameter aluminum target chamber.

NIF's laser systems have continued to mature. The master oscillator, which provides the seed laser pulse for all of NIF's 192 beams, has been demonstrated to provide the necessary precision to deliver arbitrarily shaped pulses and ignition-specific pulses. Over 75 percent of the neodymium-doped laser glass slabs that meet NIF's stringent requirements have now been produced. Over half of the potassium di-hydrogen phosphate crystal boules have been produced for optical switch plates and frequency doublers and triplers. Recent progress in mitigating and eliminating high-fluence ultraviolet optics damage has led to new manufacturing methods that will significantly reduce NIF's operating costs.

The NIF project is rapidly transitioning from a "design/build" organization into an "assemble/ install/commission" organization. To properly execute the next critical phases of the project, Integrated Product Teams (IPTs) have been formed. They are charged with ensuring that laser systems are installed to NIF's requirements and that all interface issues are coordinated during this process. Special attention has been paid to ensuring that safety remains the highest priority and that all aspects of Integrated Safety Management are followed. In this regard, the NIF project has made exceptional progress in improving its overall total recordable case (TRC) rate. The project is currently operating with a TRC of 1.5, which is significantly better than national, state, and DOE averages.

Future Milestones. As our first-light milestone approaches, scheduled for June 2004, a number of significant events are occurring. In FY 2001, a major Level 2 milestone, Final NIF Supplemental Environmental Impact Statement (SEIS) Record of Decision (ROD), was approved by the Secretary of Energy on March 30, 2001. This milestone allows operation of NIF on its current site and with current environmental conditions. Upcoming major milestones include the Level 1 End Conventional Construction, with completion and turnover of the LTAB to the Laboratory in September 2001, and a series of Management Prestart Reviews (MPR)—Level 3 milestones—that review all major installation, commissioning, and operations work on NIF prior to commencing activities. The first MPR to allow vacuum leak testing of beampath enclosures was completed in March 2001. The next MPRs to allow laser component assembly in the OAB and to allow transport and installation of laser components into NIF will begin in mid-FY 2002.

DOE/NNSA has also recently made major strides toward establishing NIF as a national user facility to its diverse set of experimental users. In FY 2001, NNSA/DP named Associate Director for NIF Programs George Miller to be the first NIF director. In this capacity, he is tasked to begin implementing governance plans for operating NIF as a national user facility. The first-draft governance plan was submitted to DOE/NNSA in April 2001, following an extended period of contribution and comment from the national security laboratories and representatives of the basic science and weapons effects communities. This plan provides for multiple levels of review and programming of NIF to ensure that the highest quality science is performed, while national security missions are met. A new NIF User Support Organization has been formed to begin implementing the governance plan and to set up the local Livermore Laboratory hosting function for experimental user communities. Current planning indicates that experiments will begin on NIF at the time of first light and will continue throughout the commissioning phase. By the time of project completion in FY 2008, over 1,500 NIF experiments will already have taken place.

2.1.6 The Accelerated Strategic Computing Initiative

The Accelerated Strategic Computing Initiative (ASCI) is a program to dramatically advance our ability to computationally simulate the performance of an aging stockpile and the conditions affecting weapon safety (e.g., the Advanced Simulation and Computing Campaign and others, previously discussed). The initiative is designed to deliver at a steady pace significant new capabilities to support stockpile stewardship. To make the needed major advances in weapons science and weapons simulation code technology, Livermore, Los Alamos, and Sandia national laboratories are obtaining from U.S. industry dramatic increases in computer performance and information management.

Situation and Issues

ASCI White and Blue Pacific. In summer 2000, Livermore became home to the world's most powerful supercomputer with the delivery from IBM of ASCI White, which is capable of over 12 trillion operations per second (12 teraops). ASCI White is based on the next-generation IBM processor, node, and switch technology and constitutes another dramatic leap in performance. It consists of 512 nodes, each with 16 IBM RS/6000 processors. ASCI White provides over 12 terabytes of main memory and over 147 terabytes of global disk space.

Exceeding its contractual performance requirements, ASCI White is about a factor of three faster than Livermore's Blue Pacific computer (3.9 teraops), which was used to perform the first-ever 3D simulation of an exploding nuclear weapon primary. Blue Pacific is a hyper-cluster of 1,464 nodes hooked together by a multiple-stage hierarchical network. Each node is a four-way, shared-memory multiprocessor with its own operating system and local disk. The system includes 17.1 terabytes of local disk memory and 62.5 terabytes of global disk memory.

ASCI and Future Facility Needs. The next supercomputer at Livermore after ASCI White will move us much closer to ASCI's goal of full-scale simulation of weapons performance based on first-principles physics models without resorting to simplified models. The threshold for that capability is 100 teraops, and reaching the goal quickly is vital to success in stockpile stewardship. Plans call for ASCI "Q" (30 teraops) to be operational at Los Alamos in 2002, followed by a 20-teraops machine at Sandia and a 60- to 100-teraops machine for Livermore. The machine at Livermore will be as close to 100 teraops as can be afforded within budget limitations. The machine will be very large, and we need the Terascale Simulation Facility to house it.

Applications Development and Validation. The unprecedented power of ASCI computers is essential to advances in simulation, but raw computer speed is not the sole barrier to progress. The development of improved software is comparably as important as new hardware to increasing the speed and power of simulations. The need for better algorithms is particularly great—and the challenge is particularly daunting—for software intended to run efficiently on machines using thousands of processors. In concert with the development of new algorithms and simulation software, careful attention must be given to assuring the quality of the enhanced codes. The Verification and Validation Program, which focuses on the development of improved validation tools and methodology, is an important component of the overall ASCI Program.

Problem-Solving Environment. In addition to acquisition of ASCI computers and efforts to develop, verify, and validate simulation codes, Livermore is working with Sandia and Los Alamos to improve the problem-solving environment (PSE). The success of these improvements is helping to accelerate the development and application by our weapon scientists of the new ASCI simulation codes to the problems of stockpile stewardship. Key elements of the problem-solving environment are advanced code-development tools, very large and fast data-storage facilities, high-speed communication links for both classified and unclassified data, and data visualization development.

Academic Partnerships. Academic partnerships are important to ASCI. Livermore is working with universities through the Academic Strategic Alliances Program (ASAP), a multi-year initiative to assist the three NNSA laboratories in meeting ASCI computational science and simulation goals. ASAP is engaging the best minds in the U.S. academic community to help accelerate the emergence of new unclassified simulation science and methodology and associated supporting technology for high-performance computer modeling and simulation.

Program Thrusts

To succeed, the ASCI Program must create leading-edge computational modeling and simulation capabilities based on advanced simulation codes and high-performance computing technologies. A new generation of weapons simulation codes is beginning to emerge, which combines advanced fundamental physics models, much greater spatial resolution, and the ability to model weapons behavior in three dimensions. Taking full advantage of these codes will require computers more powerful than the best available today.

Beyond ASCI White and the Terascale Simulation Facility. A 60- to 100-teraops ASCI computer at Livermore will be a major step toward ASCI's goal of full-scale simulation of weapons performance based on first-principles physics models. Expansion of Livermore's computing power beyond the 12-teraops platform requires construction of the Terascale Simulation Facility (TSF). The Conceptual Design Report for TSF has been approved. Design of the TSF is driven primarily by power and space requirements for future-generation ASCI-scale computers.

With timely funding, about 24,000 square feet of the machine room (of the 48,000 square feet planned) would be available and fully equipped to accept an ASCI-scale system in 2004. The building will also house the growing staff of computer and physical scientists who support the computers or work on research and development projects such as the Data and Visualization Corridors (DVCs) necessary for assimilating terascale data sets. The construction project was initiated with an FY 2000 line-item authorization.

Advanced Simulation and Computing Campaign. As discussed in Section 2.1.3, one of the Stockpile Stewardship Program Campaigns focuses on the development of 3D, high-fidelity simulation software to analyze the physics and engineering performance and safety of nuclear weapons in the stockpile. As an example, a significant accomplishment in June 2001 was the completion by Laboratory scientists of a 3D simulation of the performance of a nuclear weapon secondary. The first-ever 3D simulation of a nuclear weapon primary explosion was completed at Livermore in December 1999.

Data Management and Visualization Capabilities. A major element of the simulation environment is very-high-performance visualization capabilities. Scientists must be able to assimilate the information from simulations generating huge output files, possibly as large as many trillions of bytes from an overnight run. We are combining high-performance storage and networking with a visualization architecture that allows interactive exploration of huge quantities of data. Sophisticated new tools are being developed to store, manage, and rapidly move huge quantities of data and to summarize, organize, and analyze the information.

Improved visualization of ASCI-generated data is offered by Livermore's Data Assessment Theater in Building 132N. The theater includes 15 state-of-the-art projectors to achieve extremely high resolution and superior image quality on an 8- x 16-foot screen with 6,400- x 3,072-pixel resolution. In 2001, a second major visualization capability began operation—The Visualization Work Center in Building 111. The center is designed to function for individual use, small group interactions, and presentations to larger groups with a "Power Wall," which is driven by eight projectors (5,120- x 2,048-pixel resolution). A 3,840- x 2,048-pixel Power Wall is also in operation in Building 451 for unclassified use.

The Academic Strategic Alliances Program. Livermore is working with universities through ASAP. Universities participate in research projects funded at three levels:

• Level One Strategic Alliances. Major centers have been established at Stanford University, California Institute of Technology, University of Chicago, University of Utah, and University of Illinois. Personnel from Livermore are working with their counterparts at each center. The centers are engaged in long-term, large-scale, unclassified, integrated multidisciplinary simulation and supporting science and computational mathematics representing ASCI-class problems.

• Level Two Strategic Investigations. These investigations establish smaller discipline-oriented projects in computer science and computational mathematics areas identified as critical to ASCI success. The projects are each targeted for three years. As with Level One Alliances, these investigations are selected by an open, peer-reviewed solicitation process.

• Level Three Individual Collaborations. These projects are initiated by individual ASCI researchers and focus on near-term ASCI-related problems. They are funded from the Laboratory's ASCI budget allocation.

2.2 Countering the Proliferation and Use of WMD

Livermore is applying its nuclear expertise, developed through past work in nuclear weapons development and testing and its continuing stockpile stewardship responsibilities, to the challenge of nuclear threat reduction—that is, nonproliferation, counter-proliferation, and counterterrorism. Because the threat of proliferation is not restricted to nuclear weapons, we are also drawing on the Laboratory's broad capabilities in the biological and chemical sciences to develop the technologies, analysis, and expertise needed to deal with the proliferation of chemical and biological weapons.

These activities directly support Objective 4 of the *DOE Strategic Plan*'s National Nuclear Security Business Line: specifically to "reduce the global danger from the proliferation of weapons of mass destruction (WMD)." This work provides the technological base for those U.S. agencies with operational responsibility for characterizing foreign weapons programs and detecting proliferation-related activities, for detecting and mitigating the use of weapons of mass destruction against U.S. civilians, and for negotiating and monitoring compliance with arms reduction and other agreements. Our on-going counterterrorism efforts and capabilities, discussed in Section 2.2.2 Response to WMD Terrorism (as well as in Section 2.3.2 Critical Infrastructure Protection), have been called upon to support the newly declared war on terrorism, mounted since the attacks on the World Trade Center and Pentagon.

The primary sponsor of nonproliferation, counterproliferation, and counterterrorism programs at Livermore is NNSA's Office of Defense Nuclear Nonproliferation. Other sponsors include DoD, various U.S. intelligence agencies, and NNSA's Office of Defense Programs. Our activities are coordinated with and complement the work of other government laboratories and agencies.

Scientific and technological superiority is the foundation of U.S. national security, and research and development (R&D) plays a critical role in nonproliferation and threat reduction. Proliferation detection and intelligence collection depend on successive generations of advanced technology to overcome denial and deception and to interpret fragmentary clues amid enormous and expanding volumes of technical data and other information. The strength of international treaties and agreements is largely based on technical capabilities for monitoring compliance.

Livermore's nonproliferation and threat reduction R&D programs address four grand challenges:

- Proliferation detection.
- Response to WMD terrorism.
- Worldwide monitoring for nuclear explosions.
- Protection and control of nuclear weapons and nuclear material.

We also support U.S. nonproliferation and threat reduction efforts with our program in international assessments and through our Center for Global Security Research.

2.2.1 Proliferation Detection

Situation and Issues

The discovery of Iraq's extensive clandestine WMD programs following the 1991 Gulf War demonstrated with chilling clarity the difficulty of detecting proliferation-related activities. This experience also illustrated the need to back up agreements with effective monitoring technology. Despite the fact that Iraq had signed the Nuclear Non-Proliferation Treaty and was subject to International Atomic Energy Agency (IAEA) inspections, it managed to completely hide its WMD activities. After the dissolution of the Soviet Union (late in 1991), the DOE and its national security laboratories were tasked and funded to develop improved proliferation detection capabilities to meet this critical national security need in the increasingly complicated multipolar world.

The goal of this work is to develop technical means by which signatures associated with the development, production, and testing of weapons of mass destruction can be detected and quantified. Characterization of these signatures will provide clues that, together with other sources of information, can be used to infer the nature of suspicious activities. Because of the technical difficulty of achieving the required proliferation detection capabilities, the optimal approach is not readily apparent. Therefore, different avenues must be investigated and the state of the art advanced in many technical disciplines in order to turn proliferation detection concepts into functioning, field-worthy systems. In this area more than any other, success requires a long-term focus and sustained effort. Indeed, the proliferation detection challenge is increasing. Adversaries continue to acquire more advanced technology for their WMD programs, and they improve their denial and deception techniques as they learn about our detection capabilities.

Program Thrusts

At Livermore, we take an end-to-end approach to proliferation detection. Our technology developers work hand in hand with signatures experts, all-source intelligence analysts, and the people who develop advanced data-exploitation techniques. This systems-level approach allows us to develop technologies that meet real-world needs, function in demanding deployment environments, and deliver information that can be readily exploited and used with confidence as the basis for nonproliferation policy and counterproliferation response.

We have developed both passive and active technologies, including several long-range standoff sensors capable of measuring trace amounts of airborne effluents that are indicative of the processes occurring within a suspect facility. We conducted high-altitude flight tests of our hyperspectral infrared imaging spectrometer (HIRIS). In three flight campaigns, the system successfully demonstrated the collection of hyperspectral data under extreme environmental conditions. We have also developed continuously tunable mid-wave infrared (MWIR) lidar instruments for the multilaboratory Chemical Analysis by Laser Interrogation of Proliferation Effluents (CALIOPE) Program. In a follow-on to CALIOPE, we participate in the Metis Program, whose goal is to develop a hybrid active/passive sensor for remote chemical detection.

These sensor technologies have been transitioned from laboratory concepts into prototype fieldable systems, and their operational feasibility in complex industrial environments is being demonstrated. The next step is to work with operational agencies to integrate these detection technologies into their future technical capabilities.

2.2.2 Response to WMD Terrorism

Situation and Issues

The September 11 attacks on the World Trade Center and the Pentagon have galvanized U.S. efforts to combat terrorism and respond to grave concerns about potential terrorist use of chemical and biological weapons, particularly attacks against civilian targets. The Chemical and Biological National Security Program (CBNP) was initiated by DOE in FY 1997 to develop new technologies for improved response in the event of a chemical or biological terrorist attack. Livermore is a major participant in all aspects of this program, which is contributing to national efforts initiated after September 11, 2001.

Program Thrusts

Biological Detection. A limiting factor in the nation's ability to protect against a biological terrorist attack is the current state of biodetector technology. We are developing two classes of biodetectors: immunofluorescence-based sensors (miniature flow cytometers) and DNA-recognition instruments (based on the polymerase chain reaction, or PCR). When used in combination, these two independent, complementary assays afford the highest level of accuracy that can be achieved today.

Biodetectors depend on unique antibodies or DNA sequences to identify and characterize biological pathogens. We are developing a comprehensive array of such signatures to support a wide range of biological detection capabilities and are working closely with the Centers for Disease Prevention and Control (CDC). The first of these signatures is complete and is being made available to the national network of public health laboratories. We are also working with the Federal Bureau of Investigation, CDC, Department of Defense, and U.S. intelligence agencies to develop detailed biological "fingerprints" and data to support forensic analysis of any act of biological terrorism.

This past year, we completed testing the first truly portable, battery-powered PCR instrument, the Handheld Automated Nucleic Acid Analyzer, or HANAA. HANAA is a small (about the size of a brick) portable, battery-powered device that can be used in the field to detect the presence of pathogens such as anthrax or plague through the analysis of sample DNA. The process takes 30 minutes or less. The Laboratory has been working with an industry partner to produce commercial models of the detector.

We have also built and field-demonstrated a fully Autonomous Pathogen Detector System (APDS). The APDS is designed to operate in fixed locations, where it continuously monitors air samples and automatically reports the presence of specific biological agents. The APDS is targeted for domestic applications in which the public is at high risk of exposure to covert releases of bioagent (e.g., transportation systems, convention centers).

Incident Response. Our Nuclear Credibility Assessment Program provides technical, operational, and behavioral evaluations of WMD extortion threats. It also assesses cases of illicit trafficking of alleged nuclear materials. We are a key participant in the national Joint Technical Operations Team (the successor to the Nuclear Emergency Search Team), the Accident Response Group, the Radiological Assistance Program, and the Federal Radiological Management Assistance Capability. Upon request of the FBI, we also furnish emergency response personnel and equipment for high-visibility events and provide forensic analyses beyond the capabilities of the Bureau's own laboratories.

To provide biodefense for special events (e.g., governmental assemblies, dignitary visits, major sporting events), Livermore and Los Alamos are jointly developing the Biological Aerosol Sentry and Information System (BASIS). This system is designed specifically for the "detect to treat" mission—detecting a bioterrorism incident within a few hours of attack, early enough for public health agencies to mount an effective medical response. BASIS uses a network of distributed sampling units located in and around potential target sites. Each sampling unit continuously collects, stores, and time-registers aerosol samples. The samples are retrieved and brought to a field laboratory for analysis. If a bioagent is detected, authorities are notified and provided with information as to agent type, time and location of "hot" samples, estimated aerosol concentrations, hazard zones, and medical caseload estimates.

To ensure that BASIS supports real-world operational needs, it is being developed in close cooperation with the public health agencies (federal, state, and local) responsible for emergency response and medical operations in the event of a bioattack. BASIS was successfully field tested in an urban setting in March 2001. It is currently configured for limited-duration operations, although in the future it will be modified for long-term operations.

Once pathogens such as anthrax or plague are discovered, they need to be cleaned up. Laboratory researchers have developed L-Gel, a silica-based oxidizer material that can be sprayed onto any surface to kill biological agents. L-Gel works in less than an hour and, because it is environmentally benign, can be vacuumed away or simply left in place outdoors. The Laboratory has identified potential industrial partners to commercialize the gel and is working quickly to develop a licensing agreement to meet increased demand for the material.

Forensic Science and Analysis. The Forensic Science Center develops new technologies for detecting and characterizing the source of weapons materials. We also develop microanalytical forensic techniques, new field instruments, and sample collection techniques for use by federal and local law enforcement agencies (Section 2.3.3). The center has continuing partnerships with the U.S. military, FBI, other government agencies, and industry.

The special capabilities of the Forensic Science Center are exemplified by the fact that Livermore has begun the procedure to become certified by the Organization for the Prohibition of Chemical Weapons (OPCW) in response to a request from the U.S. State Department. OPCW implements the Chemical Weapons Convention, which outlaws chemical weapons and the transfer of chemical-weapon-related technologies. As an OPCW-accredited laboratory, Livermore would participate in testing chemical samples to determine whether the samples contain chemical weapons agents, their precursor chemicals, or their decomposition products. Under the terms of the Convention, all chemical samples must be tested at two OPCW-designated laboratories. Congress mandates that all U.S. samples must be tested in the United States. Currently, the nation has one designated laboratory, the Edgewood Chemical and Biological Forensic Analytical Center in Maryland. Livermore, with its capabilities to characterize chemicals at ultratrace levels, would become the second laboratory required for this testing.

2.2.3 Worldwide Nuclear Explosion Monitoring

Situation and Issues

Livermore has provided seismic research expertise in support of nuclear explosion monitoring for more than 40 years. The U.S. must be able to detect, locate, and identify nuclear explosions of any yield, anywhere in the world, under a wide range of possible evasion scenarios. Worldwide monitoring at the required level of sensitivity requires, in turn, a detailed understanding of the propagation of signals (radionuclide, optical, electromagnetic, seismic, acoustic) that differentiate a nuclear explosion from the enormous number of background nonnuclear events such as mining explosions, earthquakes, and lightning strikes.

Program Thrust

Livermore is developing ground-based nuclear explosion monitoring capabilities in regions of concern (e.g., Middle East, North Africa, Russia, Korean peninsula). In particular, we develop databases, methodologies, algorithms, software, and hardware systems for the Air Force Technical Applications Center (AFTAC) for its use in collecting and interpreting seismic, acoustic, and radionuclide data. A critical deliverable is the Knowledge Base, which provides regional propagation path corrections to the event processing algorithms in AFTAC's analysis pipeline. This Knowledge Base is expanded, enhanced, and calibrated as new data and interpretations become available and new monitoring stations come on line. This past year, we delivered to AFTAC parameter sets covering the Middle East and Southwest Asia. The focus of our current work is on the European Arctic, including the test site at Novaya Zemlya.

2.2.4 Protection and Control of Nuclear Weapons and Nuclear Material

Situation and Issues

The best way to stop nuclear weapons proliferation is at the source, through the protection and control of weapons-usable nuclear materials. The security of these materials in Russia is of particular concern, given that country's dire economic straits and its inability to support the Soviet-legacy nuclear infrastructure. To this end, Livermore participates in cooperative U.S.–Russian programs to secure at-risk nuclear material in Russia, dispose of excess highly enriched uranium and plutonium, and assist in downsizing the Russian nuclear weapons complex.

Livermore also assesses for the U.S. government the impact of proposed treaty provisions in terms of our ability to monitor other countries and to protect sensitive information during foreign inspections of U.S. facilities. In addition, we develop monitoring and verification technologies and participate in field trials to prepare for inspections in the U.S. and abroad. In particular, we support joint DoD and DOE transparency and verification efforts for a wide range of warhead dismantlement and fissile material activities, including warhead dismantlement transparency, Mayak (Russian) Storage Facility Transparency, IAEA inspections, highly enriched uranium (HEU) purchase transparency, the Plutonium Production Reactor Agreement, the Processing and Packaging Implementing Agreement (PPIA), and excess fissile material storage under the Trilateral Initiative (U.S., Russia, and IAEA). A major challenge to dismantlement transparency is the need for technologies that reveal enough information to verify that the inspected contents are of weapons origin without revealing sensitive design information. We have developed such a method and successfully demonstrated it to the Russians and the IAEA.

Program Thrusts

Material Protection, Control, and Accounting. For the MPC&A Program, Livermore specializes in vulnerability assessment, gamma spectroscopy, access control and security system integration, and information systems. We lead the MPC&A project teams for the Federal Information System, various Russian Navy projects, Chelyabinsk-70, Sverdlovsk-44, Bochvar Institute, and Krasnoyarsk-45; and we provide project support for an additional seven site teams. Of the various DOE laboratories involved in the MPC&A Program, Livermore is unique in its role with the Russian nuclear Navy and nuclear-powered icebreaker fleet. Since the work began in 1997, MPC&A upgrades for the four nuclear refueling ships have been completed and commissioned, two in 1997 and two more in 2000.

The work at the Russian Navy facilities has been some of the most successful of the MPC&A Program. Success is attributable to the combination of a highly focused user (the Russian Navy), an excellent subcontractor and system integrator (the Kurchatov Institute), and a highly trained team of NNSA and national laboratory personnel that has built an excellent working relationship with the Russian personnel, facilitating efficient problem solving and rapid system implementation. The success of this approach has resulted in an agreement between NNSA and the Russian Navy to expand MPC&A cooperation to include nuclear weapon storage sites. Work at a number of these sites is under way and meeting with the same success as previous activities with the Russian Navy; however, the funding for this work is at risk, which may slow down these very important risk-reduction efforts.

Plutonium Disposition. Program direction for the disposition of U.S. and Russian surplus plutonium is undergoing review by the National Security Council. Both the U.S. and Russia have agreed to dispose of 34 metric tons of plutonium, but the path forward is complex technically, politically, and economically. The U.S. has adopted a dual-track approach in its plutonium disposition program: fabrication of mixed uranium/plutonium oxide (MOX) fuel to burn plutonium in nuclear reactors and immobilization of impure plutonium in a ceramic matrix for long-term geologic disposition. Livermore has led the national plutonium immobilization program, which is responsible for disposing of 13 metric tons of impure plutonium that otherwise might end up as orphan material.

This past year, we completed testing of the can-in-canister and finished the conceptual design report for the plutonium immobilization facility in preparation for the full facility design. We also completed testing of two highly automated plutonium lines with plutonium surrogates and were scheduled to start testing the lines with plutonium in summer 2001. The first line uses hydrogen in a hydride/oxidation process (HYDOX) to transform plutonium from a metal to an oxide powder. The ceramification line then combines the plutonium oxide with ceramic precursors to form, after cold pressing and high-temperature sintering, a ceramic suitable for long-term geologic disposition in the can-in-canister.

In April 2001, we were directed to suspend our immobilization activities, while maintaining the ability to restart at a later date, in response to FY 2002 budget guidance and pending the results of program review.

Downsizing the Russian Nuclear Weapon Complex. Downsizing the Russian nuclear complex is a high-priority U.S. national security goal. However, such downsizing will eliminate the jobs of thousands of Russian weapons workers. To accelerate the downsizing process, the U.S. and Russia have launched a cooperative program to create self-sustaining civilian jobs for displaced workers in the closed nuclear cities of Sarov, Snezhinsk, and

Zheleznogorsk. Livermore leads the NNSA team working with Snezhinsk and its various civilian entities to develop commercial enterprises. In November 2000, the Strella Open Computer Center for commercial software development and scientific computations was commissioned. Former Ambassador Ronald Lehman, director of the Center for Global Security Research at Livermore, led the U.S. delegation for the official dedication.

We are also leading a medical technology development project with the Avangard Electromechanical Plant (a weapons production facility) at Sarov. In March 2000, contracts were signed by Livermore, the Avangard Foundation (the commercial element of the Avangard plant), and Fresenius Medical Care (the world's largest provider of products to individuals with chronic kidney failure with six production facilities in the U.S.) for the development of a manufacturing center at Sarov for dialysis machines and related products. This project will eventually employ hundreds of former weapons workers in the production of dialysis equipment and treatment kits. In June, fences were moved to create a Technopark for this and other commercial projects. This project represents a major milestone in U.S. government efforts to engage a Russian serial production facility.

Verification and Transparency. The nuclear science and radiation detection technology base resident at Livermore and within the NNSA nuclear complex is key to agreements with Russia to reduce the danger from nuclear weapons. During the past decade, the U.S. and Russia have engaged in negotiations on such issues as shutting down plutonium-producing reactors, monitoring nuclear stockpiles, and mutually inspecting material declared excess to defense needs. The sticking point in all of these negotiations is the need to measure attributes of classified objects while preventing the disclosure of sensitive weapons design information.

At Livermore, we conduct R&D to develop novel radiation detection instrumentation, data interpretation algorithms, information barriers, and monitoring procedures for use by U.S., Russian, and IAEA inspection personnel. A prototype detection system, employing our information barrier and autonomous shutter, was successfully demonstrated to Russian technical and security personnel at the Fissile Material Transparency Technology Demonstration, held in August 2000 at Los Alamos.

2.2.5 International Assessments

Situation and Issues

A formal program in international assessments was established at Livermore in 1965 to analyze the Soviet nuclear threat and, shortly thereafter, the Chinese threat for the U.S. intelligence community. Since then, our efforts have expanded to include nuclear as well as chemical and biological proliferation in smaller nations, rogue states, and terrorist groups. Of particular concern are the activities of threshold states (countries thought to be able to develop or produce nuclear weapons within a few years or less). We also review export license requests for the U.S. Department of Commerce and provide technical support and assistance to the U.S. intelligence community.

Program Thrusts

All-Source Analysis. We conduct all-source analysis and research related to foreign development and deployment of nuclear weapons and other weapons of mass destruction. We evaluate nuclear proliferation risks in world "hot spots," focusing on threshold states with difficult or hostile relations with the U.S. and those located in politically unstable regions. Nuclear programs in Iran, Iraq, North Korea, India, and Pakistan are of major concern. Early-stage foreign technology development and acquisition programs are of particular interest as cooperation among proliferant countries has grown to include a full spectrum of weapons technologies.

We also analyze the status of nuclear weapons and weapon materials in Russia and China. Both countries pose concerns related to nuclear proliferation; each may be the source of nuclear materials or technology, whose transfer could accelerate indigenous WMD programs. Russia's economic and political instabilities put severe stress on existing and future controls for safeguarding nuclear material and weapons inventories. China is of concern because of its uneven history related to arms control and nonproliferation and its often-strained relations with the U.S.

The Laboratory's experience and capabilities in nuclear weapons development, testing, and stewardship as well as in biological and chemical science provide the critical foundation for our assessments of WMD proliferation. The technical details of weapons information provide our analysts with the necessary information to evaluate scale and time sensitivity of proliferation threats in an integrated manner. The ability to do integrated assessments is essential because nuclear, chemical, and biological weapons programs are interrelated in some countries of concern, while other countries are pursuing chemical and/or biological weapons in lieu of more costly and more complex nuclear weapons.

Livermore assessments are based on and evaluated against the immutable laws of weapons science and provide reality checks of policy makers' understanding of foreign WMD programs. Our assessments of foreign weapons programs provide important input to policy makers and diplomats as they develop strategies for U.S. responses to events affecting national and international security.

New Secure Compartmented Information Facility (SCIF). Technology, together with the increasingly complex national security landscape, is changing the nature of intelligence work. Hardcopy reports and film imagery are rapidly giving way to massive digital files, which require high-bandwidth connectivity and modern communications and computing systems to exploit, interpret, and disseminate. The new SCIF will enable us to take advantage of this digital revolution in the intelligence business, enhancing our contribution to the intelligence community. The new SCIF will also allow us to accommodate our expanding programmatic needs for space. Assuming that funding is provided as requested, we plan to complete the SCIF by early 2004 at a total cost of $24.6 million.

2.2.6 Center for Global Security Research

Situation and Issues

The Center for Global Security Research (CGSR) brings together diverse expert communities to learn how science and technology can enhance national and international security, expanding knowledge of the policy–technology interface by exploring new substantive terrain and conducting multidisciplinary policy-sensitive studies and international outreach efforts. The center also supports CGSR fellows who study complex issues at the nexus of technology and policy.

CGSR taps the national security expertise resident at Lawrence Livermore, including its broad and deep base of science and engineering and its world-class capabilities in analysis, modeling, and simulation. The center works with Laboratory programs to sponsor workshops that involve their personnel and are synergistic with their activities. These workshops allow Laboratory scientists to interact with policy makers, academics, and other national security experts, giving all involved a better understanding of what national security policy needs from technology and what technology can and cannot do for policy.

Program Thrusts

CGSR focuses on four areas related to the intersection of technology and policy: reduction of threats associated with WMD, security implications of emerging technologies, anticipation of threats to national and international security, and the future role of military forces.

The center partners with national and international security organizations, including Stanford University's Center for Strategic and International Studies, UC San Diego's Institute for Global Conflict and Cooperation, the Monterey Institute of International Studies, the National Defense University, and the International Institute for Strategic Studies in London. Participants in our studies and workshops are drawn from throughout the U.S. government—including the Departments of Commerce, Defense, Energy, Justice, and State; the Federal Bureau of Investigation; the White House Office of Science and Technology Policy; members of Congress; the national laboratories; and U.S. and foreign universities and industry.

Recent CGSR events include two major "futures" projects: "After Globalization: Future Security in a Technology-Rich World" in 2000 and "Whither Deterrence?" in 2001. Both projects involved a series of workshops throughout the year and a concluding conference in November or December. The "After Globalization" project brought together different groups of experts to discuss the likely state of various technology fields and the technology-driven threats to the U.S. and its allies in the 2015 to 2020 timeframe. The "Whither Deterrence?" project is engaging participants in discussions of potential new threat scenarios, conventional and nuclear weapon systems policies, and deterrence strategies.

2.3 Meeting Other National Security Needs

Livermore works with DoD and other government agencies to leverage Laboratory capabilities to provide long-term research and development support to meet future national security needs.

2.3.1 Department of Defense

Situation and Issues

DoD is engaged in an effort to transform U.S. defense strategy and force structure to reflect post–Cold War threats to our security. The Secretary of Defense has completed a number of studies that have been used to shape the issues for the ongoing Quadrennial Defense Review (QDR). While final decisions and conclusions will not be known until the QDR is completed, the Defense Department intends to maximize the effectiveness of the armed forces by exploiting superior technology.

Livermore has experience and expertise in many areas of science and technology directly relevant to future defense needs, including missile defense, solid-state lasers, armor/anti-armor materials and munitions, micro- and nanofabrication, remote sensing, and sensors and sensor networks. Livermore also has a long-standing history of collaboration with DoD. For example, for more than a decade, we have been engaged in a DOE–DoD advanced conventional munitions technologies program for which we have developed new energetic materials and computer tools for the design and analysis of munitions. As a result of this partnership, the Livermore-developed high explosive, LX-14, is now used in the TOW and Hellfire missiles, and our CHEETAH code is widely used by DoD to predict the performance of propellants and explosives and to evaluate formulations of new energetic materials.

Program Thrusts

As described in Joint Vision 2020, U.S. military forces need full-spectrum dominance—the ability to defeat any adversary and control any situation across the full range of military operations. A key to this goal is information superiority, the capability to collect, process, and disseminate information while exploiting or denying the adversary's ability to do the same. Another key is innovation, by making use of both new technologies and new concepts of operations.

Dominant Maneuver. The U.S. military's ability to conduct operations quickly and decisively will heavily depend on advanced sensors, information technologies, and predictive meteorology capabilities (e.g., real-time exploitation of Livermore's Atmospheric Release Advisory Capability, ARAC, as discussed in Section 3.1.3).

We provide U.S. policy makers and military planners with information analysis tools to evaluate the implications of various actions. For example, Livermore's Counterproliferation Analysis and Planning System (CAPS) is a powerful tool for end-to-end analysis of a proliferator's WMD production capabilities and for assessing interdiction options and their corresponding consequences. CAPS is as easy to use as a Web browser, with its powerful and complex science (spectral analysis, toxic release modeling, etc.) invisible to the user. CAPS is regularly used by military planners, and the CAPS Web site is visited by more than 500 military users on a regular basis. CAPS has been identified as a unique planning tool for use by the Armed Forces and was singled out this year by the Secretary of Defense in his report to Congress on proliferation.

Livermore researchers are also teaming with academic institutions and industry to develop powerful new capabilities for multi-gigabit-per-second, secure, free-space communication links and aberration-free 3D imaging and targeting at ranges of 1,000 kilometers or more. Under the sponsorship of the Defense Advanced Research Projects Agency, the first two-year-long phase of the Coherent Communications, Imaging, and Targeting project, led by Livermore, is developing a prototype for such a system. Essential to the planned system are major advancements in spatial light modulators, which use independently movable mirrors to reflect light and rapidly correct for distortions in the atmosphere.

Precision Engagement. Livermore contributes its expertise in energetic materials, advanced conventional munitions, laser and electro-optics systems, conflict simulation models, and consequence analyses to the development of precision weapons systems that will allow the U.S. military to destroy adversary targets while minimizing collateral casualties. One area of special interest is the development of improved capabilities to defeat hardened and deeply buried targets. In one project, we are working with DoD to improve the capability of low-velocity cruise missiles to penetrate hard targets. Laboratory researchers have tested a prototype of a new multicharge precursor warhead, consisting of a cluster of small charges with a single large charge in the back. It is designed to efficiently create a large hole in a hardened target for the cruise missile to penetrate virtually unimpeded.

Full Dimensional Protection. The Laboratory also pursues technologies pertinent to missile defense. For example, Livermore researchers are evaluating for DoD sponsors a variety of concepts for advanced theater missile defense and for national defense against ICBMs. We analyze the capability of various interceptor systems to defend against and negate the effects of ballistic-missile-delivered WMD. Through a combination of calculation and experiment, we assess the damage and probability of kill resulting from the impact of a kinetic-energy interceptor onto an incoming ballistic missile.

We are exploring the use of the echelle grating spectrometer (EGS) for acquiring optical signatures to determine the type of incoming warhead (nuclear, chemical, or biological) following the intercept of a hostile missile. Our goal is to develop real-time characterization of impact and debris to provide battle commanders with a rapid identification of enemy warheads that have chemical or biological agents and with source terms to track those agents. We are studying the optical signatures that might be accessible to remote-sensing instruments. In early field tests of this concept, the EGS performed flawlessly and returned useful booster plume and thruster signature information.

In support of the Army's Space and Missile Defense Command, the Laboratory is also working with industrial partners to develop a 100-kilowatt average-power, solid-state laser to be deployed on a mobile battlefield platform. High-power laser systems are leading candidates for an enhanced air-defense capability. In 2000, we brought into operation a 10-kilowatt prototype laser and tested its ability to damage selected materials. The laser was delivered to the High-Energy Laser Systems Test Facility (HELSTF) at White Sands Missile Range in 2001.

In another project, we demonstrated critical capabilities that future microsatellites will need to perform complex autonomous operations in the proximity of other space objects using an engineering test vehicle (ETV) in experiments at Livermore. With its novel object-tracking system and miniaturized propellant system, the ETV has repeatedly succeeded in docking with another object in dynamic experiments on an air table that simulates zero-gravity conditions.

Focused Logistics. Livermore's conflict simulation capabilities are being applied to logistics issues for efficiently supplying equipment, which can make a decisive difference early in a military operation and dramatically reduce overall costs. For example, our Joint Conflict and Tactical Simulation (JCATS) allows training, planning, and analysis from the campaign level (hundreds of square kilometers) to individuals fighting inside a multistory building. It can model all types of terrain (land, marine, air, urban), different types of military assets and weapons, and even the level of fatigue of individual soldiers. JCATS is used by more than 70 organizations, including the U.S. military commands and services, intelligence agencies, State Department, Secret Service, and DOE site security, for training, planning, and analysis of a wide spectrum of military and security operations. In March 2000, JCATS Version 2.2 was delivered to the Joint WarFighting Center, and in May 2000, the efforts of the JCATS team were recognized with a Modeling and Simulation Award from the Defense Department's Defense Modeling and Simulation Office.

2.3.2 Critical Infrastructure Protection

Situation and Issues

Continuing attempts by hackers to disrupt government and commercial computer resources, such as the Code Red worm, together with increasing strains on regional energy power grids, as evidenced by California's electricity shortages, emphasize the national security importance of critical infrastructures. Presidential Decision Directive 63 (1998) tasked DOE and its laboratories to include critical infrastructure protection as part of their national security mission. This problem is extremely complex and exacerbated by the threat of terrorist actions. Solving it requires effective partnerships among law enforcement, industry, academia, and the technical community.

Program Thrusts

Cybersecurity. The U.S. must be able to defend critical infrastructures from nation-state, terrorist, or hacker attacks and exploit information technology as a defensive strategy. We are developing a comprehensive technological basis for information assurance activities that will allow researchers, policy makers, and implementers to understand and begin to address the problems posed by the nation's (and the world's) growing reliance on massive information networks.

Capabilities in cybersecurity are concentrated in the Laboratory's Information Operations and Assurance Center (IOAC). Over the past several years, we have developed toolsets to model and visualize information networks, analyze vulnerabilities, and simulate attacks and fixes. The Iowa toolset models information networks, graphically visualizes them, and analyzes them for attributes and patterns of interest. The Nevada toolset provides a vulnerability analysis capability, and the Minnesota toolset provides the simulation and "gaming" capability.

We assist any DOE facility that experiences a computer security incident with analysis, response, and restoration of operations. Our Computer Incident Analysis Center (CIAC) serves as DOE's watch and warning center, notifying the complex of vulnerabilities that are being exploited, specifying countermeasures to apply, and providing a picture of the attack profile. CIAC also develops science and technology solutions in support of computer network defense. In FY 2000, the CIAC incident response team issued 73 bulletins and 14 alerts and logged 7,596 incidents from 67 sites. Although these figures represent an increase of more than 50 percent in the number of incidents detected and reported, the number of successful intrusions decreased. CIAC's SafePatch has become a key element of the Air Force's cyber defense program. SafePatch is also being considered by the General Services Administration (GSA) for deployment to all federal agencies. In November 2000, the SafePatch product and its development team received a Government Technology Leadership Award.

2.3.3 Support to Law Enforcement

Situation and Issues

The DOE laboratories are working with the Departments of Justice, Commerce, and Treasury to provide law-enforcement agencies with cutting-edge, crime-fighting technologies. The May 1998 memoranda of understanding between DOE and the FBI, the U.S. Customs Service, and the Bureau of Alcohol, Tobacco, and Firearms establish formal working relationships to facilitate the transfer of DOE technology and technical expertise to law enforcement.

Program Thrusts

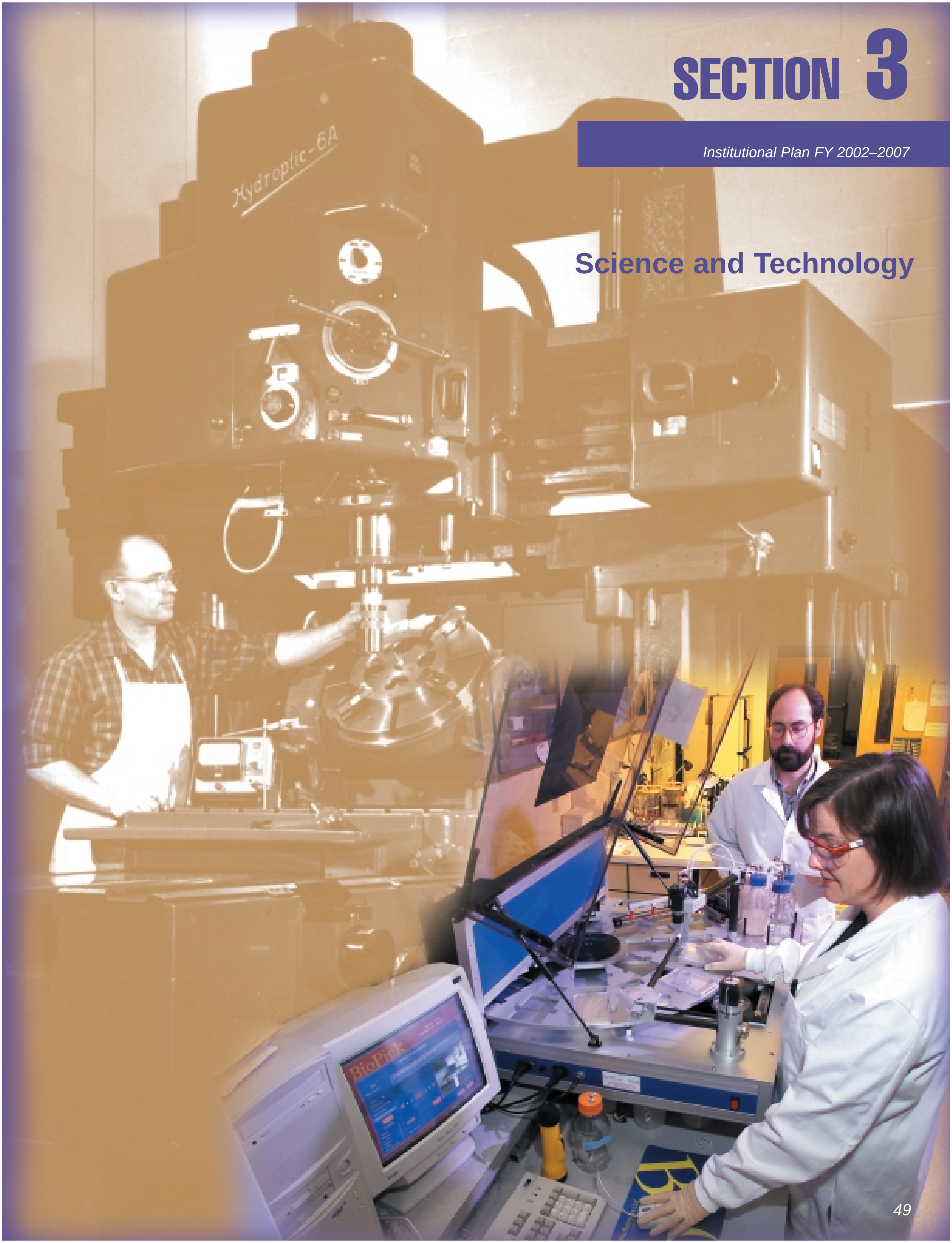
Law enforcement can benefit from Livermore technologies that were developed initially for on-site inspection of arms control treaties, detection of WMD proliferation activities, and response to WMD incidents. An example is our 54-pound, portable gas chromatograph/mass spectrometer (GC/MS), a system for quickly analyzing samples at the scene of a crime or accident. Potential law-enforcement uses for this instrument, which can identify chemicals to parts-per-billion sensitivity, include on-the-scene analysis of clandestine drug labs or unknown chemical releases, spills, or accidents. This GC/MS system can identify the substance in question within 15 minutes, greatly facilitating on-scene investigation and evidence collection. The technology for this field-portable GC/MS is being transitioned to industry for commercialization.

Other technologies with potential application to law enforcement include thin-layer chromatography (TLC) and solid-phase microextraction (SPME, pronounced “spee-mee”). Our portable TLC system can simultaneously analyze 100 samples for high explosives and other chemicals. A digital-camera image-capture system interprets the TLC results and provides first responders with a simple readout of the compounds detected. For SPME, we have combined optical fiber technology with ultratrace analysis to create a “chemical dipstick.” This technology can be used to collect minute samples indicative of the presence of illegal drugs or other chemicals of interest to law-enforcement agencies. SPME samples can be secured, preserving chain of custody, for later analysis or inserted directly into the portable GC/MS for immediate analysis.

SECTION 3

Institutional Plan FY 2002–2007

Science and Technology



THE Department of Energy has enduring missions that are vital to the national interest. In addition to providing for national security, the Department's other priorities include enhancing the nation's energy security, developing and making available clean energy technologies, cleaning up former nuclear weapons sites, developing effective and timely approaches for nuclear-waste disposal, and applying DOE's research capabilities to advance fundamental scientific knowledge and contribute to U.S. technological innovation.

Lawrence Livermore supports these DOE mission priorities to meet enduring national needs through major research activities in selected areas. We pursue projects in which we can make unique and valuable contributions. These activities build on and reinforce the Laboratory's key strengths. The nation benefits from the application of our special skills to a wide range of national problems and from the cross-fertilization of ideas. In turn, program diversity keeps the Laboratory vital and helps to sustain the multidisciplinary base needed for national security work.

Major Research Areas

Three of the Laboratory's strategic councils set the strategic direction of Livermore's programmatic efforts to meet enduring national needs. The Council on Energy and Environmental Systems, the Council on Bioscience and Biotechnology, and the Council on Strategic Science and Technology are responsible for tactical planning and formulating a strategy for long-range program and resource development in their areas of interest. Livermore has programs and plans in three major research areas.

Energy and Environmental Programs. The importance of long-term research to help provide the nation abundant, reliable energy together with a clean environment is made clear in the *National Energy Policy* report, developed for the President and published in May 2001. Livermore's energy and environmental programs contribute to providing the scientific and technological basis for secure, sustainable, and clean energy resources for the U.S. and to reducing environmental risks. Our efforts focus on critical thrust areas in which the Laboratory can make a difference: nuclear systems and materials management; global energy, carbon, and climate issues; and environmental risk reduction.

Work in these areas draws on and helps to strengthen the special capabilities that the Laboratory needs for its national security mission. The projects benefit from Livermore's multidisciplinary approach to problem solving as well as very advanced computers and simulation capabilities. We have an ability to achieve a comprehensive understanding of issues through end-to-end analysis, and we have a research approach that includes basic science, computational modeling, laboratory and field experiments, and prototype development.

Bioscience and Biotechnology. Bioscience research at the Laboratory advances human health by leveraging our physical science and engineering capabilities and focusing on genomics, disease susceptibility identification and prevention, and improved health care and medical biotechnology. The cross-fertilization of ideas that occurs at a broad-based national laboratory is important to these programs, as is the availability of the latest technologies in physical sciences and engineering.

Fundamental Science and Applied Technology. We also pursue initiatives that bolster Livermore's research strengths, further develop the science and technology areas needed for the Laboratory's national security mission, and contribute to solving important national problems. Many of these activities are funded by DOE's Office of Science or are supported by Laboratory Directed Research and Development (LDRD) to extend Livermore's capabilities in support of current and new mission requirements.

Alignment with DOE's Strategic Plan

Livermore's strengths are well matched to the DOE's needs (and selected special needs of other customers), particularly in areas with high payoffs that entail significant scientific and technical risk. In addition to our national security efforts, we contribute to the strategic goals of other major DOE business lines described in the September 2000 *DOE Strategic Plan*:

Energy Resources. Promote the development and deployment of energy systems and practices that will provide current and future generations with energy that is clean, efficient, reasonably priced, and reliable.

Environmental Quality. Aggressively clean up the environmental legacy of nuclear weapons and civilian nuclear research and development programs at the Department's remaining sites, safely manage nuclear materials and spent nuclear fuel, and permanently dispose of the nation's radioactive wastes.

Science. Advance the basic research and instruments of science that are the foundations for DOE's applied missions, a base for U.S. technology innovation, and a source of remarkable insights into our physical and biological world and the nature of matter and energy.

Partnerships and Collaborations

Much of our work to meet enduring national needs is executed in partnership

Table 3-1. General goals of Livermore thrust areas with dimensions in energy, environment, and national security.

Goals in: \ Thrust Areas:	Nuclear Systems and Materials Management	Energy, Carbon, and Climate	Environmental Risk Reduction
Energy Use **Wisely manage:**	Nuclear materials	Improved generation and use	Benefits and risks of energy options
Environment **Clean up/reduce:**	Nuclear legacy	Fossil-fuel emissions and greenhouse gases	Toxic materials and carcinogens
National Security **Reduce:**	Nuclear dangers	Dependence on imported oil	Environmental disaster risks

with industry, academic institutions, and other laboratories. Partnering activities span a wide range—from very large-scale strategic alliances to licensing of individual technologies, academic research, educational outreach, and support for the small business community. Often partnerships and collaborations are the most cost-effective way for us to accomplish programmatic goals. In addition, Livermore has a responsibility to move appropriate technologies developed in the course of our mission work into the marketplace, where the advances can have the maximum positive impact on the U.S. economy or other important national priorities.

3.1 Energy and Environmental Programs

The future security of the U.S. and the world depends on increased access to clean energy and on the preservation of a healthy environment. As made clear in the *National Energy Policy*, dependable, affordable, and environmentally sound energy for the future requires a comprehensive long-term strategy that entails the development and use of leading-edge technologies. Many important advances are needed that will require effective partnerships between private industry and government.

Livermore's role is to apply its core capabilities to enduring national needs that require innovative science and technology. The Laboratory is a leading science and technology laboratory in energy and environment. As a resource to government, in partnership with industry and universities, we develop new energy and environmental capabilities for the nation. Our expertise and accomplishments in these areas enhance the Laboratory's primary mission in national security in two ways:

• By focusing our energy and environmental programs in research areas that have important national security aspects, such as nuclear materials management. These activities are natural extensions of—and are often tightly connected with—our national security mission (Table 3-1).

• By extending the scale, technical reach, demonstration orientation, and expertise that support Livermore's national security mission. The programs add to the intellectual vitality of the Laboratory and help support the technology base needed to provide for national security. For example, expertise in geophysics and atmospheric science are needed to monitor nuclear test activities worldwide and to model atmospheric releases of hazardous substances.

The principal goals of our energy and environmental programs are to provide the scientific and technological basis for secure, sustainable, and clean energy resources for the U.S. and to reduce environmental risks to U.S. interests. Reaching these goals will require significant technological advances as well as broad cooperation among institutions. Our efforts focus on three critical areas in which the Laboratory can make a significant, positive difference.

Nuclear Systems and Materials Management. With the need for additional sources of clean energy, there is a resurgence of interest in nuclear power as a contributor to the nation's energy supply. The *National Energy Policy* recommends that "the President support the expansion of nuclear energy in the United States as a major component of our national energy policy." The report further recommends that the U.S. "should re-examine its policies to allow for research, development and deployment of fuel conditioning methods . . . and enhance proliferation resistance." Even in the absence of an expansion of nuclear energy, DOE will be responsible for a vast array of nuclear materials for generations to come. Nuclear materials management is a fundamental, compelling, and enduring mission of the Department.

Livermore is a key contributor to the development of nuclear technologies and the management of nuclear materials through our stockpile stewardship and nonproliferation activities. We also support DOE's programs aimed at secure storage, immobilization, and sequestration of radioactive materials. In addition, the Laboratory pursues research and development for fission energy systems, with emphasis on geologic repositories—Yucca Mountain and other international sites—and complementary technologies such as safeguards, transportation and packaging, and proliferation-resistant technologies for reactors and their nuclear fuel.

Energy, Carbon, and Climate. The Earth's resources are finite, and expanding economies around the world are putting stress on traditional sources of energy and natural systems. Current technologies are not adequate to meet growing demands, and human activities (such as reliance on burning fossil fuels to meet energy needs) continue to increase the atmospheric concentration of CO_2 and other greenhouse gases. Significant, large-scale innovations are needed to provide clean, accessible, non-resource-depleting energy production.

In areas where the Laboratory has special expertise, we will selectively pursue increased understanding of the links between energy use and climate change, advanced energy technologies focused on end-use efficiency, the use of lower-carbon fuels, and CO_2 sequestration. Livermore focuses on important aspects of carbon management and contributes to scientific and technical assessments of carbon-management strategies. We will also develop a better understanding of the environmental consequences of energy generation and use, which will drive technology selection and implementation.

Environmental Risk Reduction. DOE's environmental responsibility, dealing with the legacy of Cold War nuclear weapons production, is a major task. At Livermore, we are developing a better understanding of the underlying science related to the fate, transport, and effect of radionuclides in the environment. In addition, we are developing technologies to characterize and remediate contaminated groundwater faster and more cost efficiently than previously possible. Opportunities exist to accelerate cleanup at DOE contractor sites and to apply the technologies more broadly.

The Laboratory also has extremely sensitive techniques for determining the mutagenic and carcinogenic potency of chemical pollutants. We will develop new technologies that reduce the time and cost to achieve specific risk reductions, and we will advance the scientific basis for risk assessment and regulatory reform. A particular focus of our efforts will be environmental analysis of fuel additive alternatives. More generally, Livermore is capable of providing assessment and effective response capabilities needed to deal with a wide range of natural and man-made risks and disasters that pose threats to the environment and international security.

3.1.1 Nuclear Systems and Materials Management

Situation and Issues

Need for an Integrated Approach. DOE will be responsible, both internationally and domestically, for nuclear materials for generations to come. Proper management of nuclear materials is an important strategic objective of DOE that is tied to the Department's missions in national security, energy resources, and environmental quality. National security concerns give rise to the need to develop proliferation-resistant nuclear energy technologies for international use as well as technologies to better manage and control nuclear wastes. Current environmental and safety issues—waste cleanup, interim storage, and long-term repositories—dominate domestic concerns. There is also a resurgence of interest in exploring next-generation nuclear technologies to provide energy security.

Because issues related to nuclear systems and materials cut across mission areas, DOE would benefit from an integrated approach to ensure secure, safe, and environmentally sound use of nuclear materials throughout their life cycle. The potential direct benefits include increased efficiency, reduced costs, and greater safety as the DOE carries out its stockpile stewardship and nonproliferation missions, contributes to the advancement of nuclear energy, and meets its obligations in material disposition, waste management, and environmental cleanup. In addition, an integrated approach will better enable decision makers to focus on the most critical factors, leading to an integrated set of capabilities that the U.S. can use to proactively deal with important nuclear issues in the 21st century. Success will also help preserve the options for nuclear power and maintain leadership in the international nuclear materials arena.

Livermore's Capabilities and Contributions. Livermore is outstanding among U.S. national laboratories in both the scope and focus of nuclear activities. In addition to weapons research and development, we work on aspects of nuclear systems and materials associated with civilian use. Our activities span national security aspects (materials disposition, waste management, and proliferation-resistant technologies) and energy and environmental concerns (technologies for storage, improved safety and security, transportation, repositories, and cleanup). This experience base gives Livermore the expertise and ability to provide key elements of a comprehensive national program for management of nuclear systems and materials.

Program Thrusts

Yucca Mountain Project. Livermore is working to resolve issues regarding long-term storage of high-level nuclear waste. For the Yucca Mountain Project, we have played a major role in the design of the storage canister and engineered barrier, pioneering the approach of using waste-generated heat to keep the storage environment dry and leading in the development and evaluation of waste package materials and designs. We are working to support major project milestones toward site recommendation and license application, and in these efforts, we have placed significant emphasis on achieving high quality assurance. Livermore staff members led the preparation of three of the nine Process Model Reports—waste package, engineered barrier system, and near-field environment—that will provide the basis for the Secretary's site recommendation to the President. Livermore is also making substantial contributions in the waste-form program area.

Licensing of the Yucca Mountain facility will likely require more scientific tools in modeling and performance confirmation. We are developing an integrated repository systems model that includes water infiltration, thermal effects, and reactive flow of radionuclides. We are also initiating development of an even more complete materials system modeling capability that will include the engineered system of man-made materials as well as the perturbed natural geologic system. This work, which takes advantage of dramatic increases in computational capability at Livermore, will help in optimizing and evaluating the technical performance of the repository.

The reactive transport modeling capabilities that Livermore is developing are a recognized resource for other DOE environmental restoration plans and projects—at Hanford and at Idaho.

Nuclear Safety and Security Systems. As part of its nonproliferation mission, Livermore contributes to DOE's Material Protection, Control, and Accounting (MPC&A) Program to improve the security of weapons-usable nuclear materials in the former Soviet Union (see Section 2.2.1). For example, we participate in DOE's Second Line of Defense Program, through which we are helping the Russian Customs Service install detection equipment to intercept illicit traffic in nuclear materials at Russian border crossings and checkpoints.

We have also developed technologies to improve the physical security and protect sites in the U.S. that contain nuclear material or other top-priority assets. A sophisticated, computerized security system called Argus was designed, engineered, and installed at Livermore. Argus is now being installed at other DOE facilities (Idaho National Engineering and Environmental Laboratory, Pantex, and Los Alamos) and DoD facilities. A key feature of Argus is planned renewal so that the installed systems are continuously upgraded and therefore never become obsolete. To sustain such renewal, a major element of our program involves improvements to current components and new products to enhance Argus.

In the area of nuclear safety, Livermore's Fission Energy and Systems Safety Program works with the Nuclear Regulatory Commission (NRC) to develop software and computer-system design guidance that it uses to evaluate the design of safety-critical systems for U.S. plant retrofits. Overseas, where new nuclear power plants are being built, regulators and designers are using this state-of-the-art guidance to help ensure plant safety. In addition, Laboratory experts, using sophisticated risk assessment models, work with DOE and the NRC to analyze the transportation of spent nuclear fuel. We also review safety analysis reports for packaging with regard to federal regulations and develop evaluation criteria for the NRC and DOE.

Materials Management. In 1993, the U.S. signed an agreement with Russia to purchase highly enriched uranium (HEU) extracted from Russian nuclear weapons. Under this agreement, the HEU is blended down in Russia to low-enriched uranium (LEU) and then shipped to the U.S., where the LEU is used in making fuel for nuclear power reactors. Livermore is providing comprehensive technical support for transparency measures that serve as a technical basis for assuring each government that the other is abiding by the agreement. With funding from the NNSA Office of Defense Nuclear Nonproliferation, our

HEU transparency project activities include on-site monitoring using specially designed instrumentation, documentation review, and data analysis.

Proliferation-Resistant Technologies. New approaches are needed to stimulate growth in the use of nuclear energy in the U.S. Technological innovations offer possibilities for making nuclear reactors inherently more safe and nuclear materials in the fuel cycle more resistant to misuse. Proliferation-resistant technologies are receiving significant attention in the U.S. and internationally. We are helping in the planning of U.S.–Russian activities that focus on advancing proliferation-resistant technologies for nuclear reactor systems and developing a spent-fuel repository in Russia. Livermore is also pursuing ideas for partnerships with other laboratories to demonstrate proliferation-resistant technologies and systems.

More generally, the Laboratory is taking a systems approach to determine how to make the nuclear fuel cycle more resistant to proliferation through advanced technologies and improved systems and control features. A systems approach is embodied in our Nuclear Energy Proliferation Assessment and Research Capability (NuPARC), which we are developing by linking together relevant multidisciplinary expertise throughout the Laboratory. We are also engaged in a variety of research and development activities for advanced, proliferation-resistant fuel cycles.

3.1.2 Energy, Carbon, and Climate

Situation and Issues

Carbon Management. Carbon-based fuels will remain the primary avenue of energy production for the coming decades. Continued use of carbon fuels may increase carbon dioxide levels in the atmosphere with possible environmental consequences. The Laboratory is applying its computational resources to assess the character of these possible environmental consequences and to identify climate-change influences on the storage and movement of carbon through the Earth's land, ocean, and atmospheric systems.

The Laboratory is also addressing carbon management through improved technology. Three strategies are being advanced: (1) Movement to lower-carbon fuels, e.g., using natural gas instead of coal or petroleum and enabling the use of manufactured low-carbon fuels such as methanol, liquefied natural gas, and hydrogen. This strategy also includes the development of carbonless electricity production. (2) Improvement in the energy efficiency of all use sectors, including utilities, transportation, industrial, and residential. (3) Development of low-cost separation and carbon-sequestration technologies.

Energy Alternatives. The need for clean, reasonably priced, reliable energy calls for new exploration, production, and utilization methods for hydrocarbon fuels. The Laboratory's strengths in earth and environmental sciences, materials science, engineering, and computational modeling will be applied to develop more efficient coal combustion, energy storage and conversion, renewable resources, and emission separation and sequestration technologies. We are also pursuing fusion energy science as a possible longer-term source of energy (see Section 3.3.1).

Transportation Systems. Transportation systems are a leading contributor to greenhouse gases and increasingly will be targeted for CO_2 emission reductions. About 30 percent of the global CO_2 emissions from fossil-fuel stems from the use of oil for transportation. Livermore's expertise and programs in advanced materials, systems modeling, alternative fuels (e.g., hydrogen and natural gas), and energy conversion and storage (e.g., fuel cells for mobile applications) provide the basis for expanded work in this area. The U.S. currently imports 57 percent of its petroleum, which is about the amount that the U.S. uses for transportation. Continued increases of oil imports have important national security implications.

We have completed a number of important computational studies dealing with the combustion of diesel fuels for improved efficiency and reduced emissions. Our combustion models were used to clarify and validate many of the experimental results obtained at Sandia National Laboratories' Research Center. We also contributed to the study of combustion of oxygenated hydrocarbon fuels in diesel engines and their effectiveness in reducing soot production. In addition, Livermore is contributing to the Integrated Vehicle Electronics Simulations Testbed (InVEST) Program and other partnerships to develop next-generation vehicles through both simulation efforts and technology development.

Grand Challenge of Climate Modeling. A grand challenge that faces the international scientific community is determining the record of Earth's climate over recent centuries and assessing whether humans significantly affect global and regional climate. As a major contributor to the international global climate modeling effort, Livermore supports DOE's mission to understand the environmental consequences of fossil-fuel use by capitalizing on the Laboratory's strengths in atmospheric sciences and the application of terascale computing to simulation science (e.g., climate models). The Laboratory's unclassified computational capability is made available through institutional investments that augment NNSA's Accelerated Strategic Computing Initiative (ASCI).

The *National Energy Policy* recommends "that the President direct federal agencies to support continued research into global climate change." Livermore is a key participant, along with several other DOE laboratories and the National Science Foundation's National Center for Atmospheric Research (NCAR), in the newly launched DOE Accelerated Climate Prediction Initiative (ACPI). This initiative will develop a next-generation climate model that includes advances in computational structure and scientific capabilities. Livermore has leadership responsibilities in three areas of the ACPI: (1) parallelized implementation and optimization of new dynamic cores, (2) creation of an interactive ozone (i.e., non-greenhouse gas) chemistry capability, and (3) analysis of very high-resolution climate simulations.

In addition, Livermore has major responsibilities for the Program for Climate Model Diagnosis and Intercomparison (PCMDI), which was established at the Laboratory in 1989. PCMDI's principal mission is to develop improved methods and tools for the diagnosis, validation, and intercomparison of global climate models and to engage in research on a variety of outstanding problems in climate modeling and analysis. (For an overview of the intercomparison projects currently under way, see http://www-pcmdi.llnl.gov/.)

Program Thrusts

Fossil and Geothermal Energy. Through 2050, most of our energy requirements will be supplied by fossil energy. We need to develop technologies to enhance the recovery of oil and gas (currently two-thirds of the oil is left in the ground). The Laboratory participates in DOE's Natural Gas and Oil Technology Partnership, an alliance that combines the resources and experience of the nation's petroleum industry with the capabilities and technologies of the national laboratories. This integration expedites development of advanced technologies for better diagnostics, more efficient drilling, and improved natural gas and oil recovery.

We will also explore other technologies that can lead to significant, large-scale innovations in energy production or that can help manage carbon emissions. These efforts build on the Laboratory's strengths in materials, instrumentation, and computational modeling. For example, the potential uses of methane hydrates are so numerous that we must thoroughly understand them. We have conducted preliminary laboratory studies on CO_2 and CH_4 clathrates and are looking to expand these efforts to understand the engineering consequences of recovery options.

Energy Conversion and Storage. We will expand the existing technology base for integrated alternative-fuels production, fueling, and automotive drive-system conversions. Widespread applications are likely in both distributed generation and transportation.

We will develop technologies for very efficient steam electrolysis, auxiliary energy storage capabilities (flywheel and supercapacitors), and the practical, safe storage of hydrogen fuel onboard a vehicle. For example, we have made significant progress on our high-temperature steam electrolyzer project, which is funded through the Hydrogen Program within DOE/EE/Office of Power Technologies. We have completed a feasibility study of decreasing electricity consumption by using both natural gas and electricity to produce hydrogen. Laboratory researchers also improved manufacturing technologies for electrolysis cell fabrication and developed new electrode materials.

Terascale Model Development—Global to Local Scales. Our goal is to be a leader in developing and integrating predictive atmosphere–ocean models on a global-to-local scale. Using coupled atmosphere–ocean simulation codes integrated with (possibly real-time) data from satellites and other sensor systems, we are striving to achieve unprecedented prediction, speed, and accuracy in climate, weather, and atmospheric dispersion modeling.

We are working to develop more accurate climate, chemistry, and weather forecast models, including the application of high-resolution global models to study regional-scale phenomena. Through predictions and measurements on a regional scale, we can observe and better understand the potential effect of human activities on global climate. Better climate, chemistry, and weather models require an improved understanding of the relationships among the atmosphere, ocean, and land systems. Use of these models will facilitate responsible environmental management, reliable climate predictions, and anticipation of and effective response to natural and terrorist environmental emergencies.

Laboratory researchers are improving global models by expanding the scope of simulations (e.g., coupling models of the atmosphere and ocean and, ultimately, the carbon cycle) and improving parametric models of chemical and physical processes. One area of considerable effort is the application of these models to the Laboratory's large-scale parallel computers, thereby increasing the simulation complexity and enabling simulations at unprecedented resolutions. As an adjunct to these efforts, we are developing better methods for managing and visualizing the vast amount of data generated.

Coupled Climate and Carbon Modeling. Through the Integrated Climate and Carbon Cycle Initiative (INCCA), we are developing a simulation capability that interactively couples climate and carbon-cycle models. Progress on INCCA will depend on effective collaborations with many partners and continuing support from DOE, NASA, and other sponsors. In coupling the oceans and atmosphere with the carbon cycle, improvement is needed particularly in subgrid-scale (unresolved) processes, such as local air–sea material and energy exchange and mixing and sea-ice thermodynamics. It is through atmosphere and ocean biochemical and terrestrial ecosystem processes that changes in the global and regional environments are most readily manifested. These changes are both the best diagnostics and the most important effects of global climate changes. Eventually, our models must couple all of these processes at all of the relevant scales—a daunting challenge.

Ocean Carbon Sequestration. Carbon dioxide emissions from fossil-fuel use may adversely affect global climate. The oceans naturally absorb about one-third of the carbon dioxide from human-caused emissions, but climate change could be mitigated if a way could be found to accelerate the ocean's absorption of carbon in an environmentally acceptable way. To develop the scientific base needed to make technical and policy decisions, Lawrence Berkeley and Lawrence Livermore national laboratories are codirecting the DOE Center for Research on Ocean Carbon Sequestration. Participating institutions also include the Massachusetts Institute of Technology, Rutgers University, Scripps Institution of Oceanography, Moss Landing, and Pacific International Center for High-Technology Research (PICHTR).

The center's goal is to better understand the efficacy and environmental effects of various ocean sequestration options, including direct injection of carbon dioxide into the deep ocean and fertilization of marine biota. Livermore's role in the center includes leading efforts to numerically simulate ocean carbon sequestration. We are also developing criteria for identifying subsurface geologic formations useful for sequestration.

Geologic Sequestration of Carbon Dioxide (GEO-SEQ). Roughly one-third of the 1.5 billion tons of carbon emissions in the U.S. come from power generation plants, principally those that are coal fired. These point-source emitters provide an opportunity to capture and sequester carbon dioxide at suitable local or regional geologic sites. Some underground geologic formations have structure, porosity, and other properties that make them ideal CO_2 storage sites. These are structures that have stored crude oil, natural gas, brine, and CO_2 over millions of years.

The GEO-SEQ project has been established to investigate safe and cost-effective methods for geologic sequestration of CO_2. The project is a public–private research and development partnership that is led by Livermore, Berkeley, and Oak Ridge national laboratories and involves the participation of other laboratories, universities, and petroleum industries. Targeted tasks address (1) siting, selection, and longevity of optimal sequestration sites; (2) lowering the cost and risk of geologic storage and decreasing implementation time; and (3) identifying and demonstrating cost-effective and innovative monitoring technologies to track migration of CO_2.

Energy/Environment Analysis Program. Building on the successes achieved with our Counterproliferation Analysis and Planning System (CAPS, as discussed in Section 2.2), we are beginning to develop a simulation and analysis system for studies of energy infrastructure. The system will assist in evaluation of siting, operations, and policy scenarios. Early applications of this tool may include study of issues in California, which is in the midst of an energy crisis. Several other research activities responsive to California's energy needs are also ongoing.

3.1.3 Environmental Risk Reduction

Situation and Issues

Remediation Technologies and Risk Assessment. Livermore's recent innovations in remediation technology and tools to assess the health risk from low-level exposure to toxic materials can be used to significantly reduce the national mortgage of environmental cleanup. In a demonstration of an innovative remediation technology in Visalia, California, more than 150,000 gallons—about 1.2 million pounds—of toxic chemicals have been removed in the first 30 months of operation. The work was executed by Southern California Edison, with consulting assistance from Livermore and the University of California. The technology used at Visalia—combining dynamic stripping and hydrous pyrolysis/oxidation—is in the process of commercialization. The technology is now being used for cleanup at Portsmouth, Ohio, and Cape Canaveral, Florida.

The Visalia cleanup activities demonstrate end-to-end capabilities at Livermore: understanding the underlying science, developing and applying state-of-the-art simulations, assessing environmental risks and potential clean technologies, and developing and deploying field-scale systems. Moreover, Livermore offers a portfolio of characterization, assessment, control, and remediation technologies demonstrated through work with industrial partners. For example, we have shown that we can characterize a distal underground plume and pull the plume back by using pump-and-treat techniques.

In addition, we have advanced capabilities to assist in risk assessment. For example, we are using accelerator mass spectrometry to assess the effects on human health of carcinogens at realistic exposure levels in the environment. This science and technology can greatly improve the effectiveness of remediation strategies in reducing health hazards.

Emergency Response Capabilities. Livermore has assessment and effective response capabilities needed to deal with a wide range of natural and man-made risks and disasters that pose threats to the environment and international security. With atmospheric modeling capabilities, terascale computers, and national security access and responsibility, Livermore is poised to develop the nation's premier capability for atmospheric dispersion prediction and emergency response on all critical time scales and space scales around the globe.

The National Atmospheric Release Advisory Center is located at Livermore, and we are responsible for the Atmospheric Release Advisory Capability (ARAC). ARAC is a formally recognized national emergency response service for real-time assessment of atmospheric releases involving nuclear, chemical, biological, and natural hazardous materials. ARAC's primary function is to support DOE and DoD in the event of radiological releases. Under the Federal Radiological Emergency Response Plan, ARAC staff also assists other federal agencies, and with approval of DOE, it supports local, state, and international agency responses to natural and anthropogenic releases. Since 1979, ARAC staff has supported more than 1,000 exercises and over 180 alerts, accidents, and disasters involving radiological and chemical releases.

Program Thrusts

Basic Research on Environmental Cleanup. To reduce the cost of environmental cleanup and make it faster over the long term, DOE is sponsoring projects in basic science related to environmental management through its Environmental Management Science Program. In grants from the program, our work ranges from molecular geochemistry to a large-scale look at contaminant movement at the Livermore site. Through several projects, we are studying the movement of contaminants in the vadose zone, a region between the surface and the water table that protects the water from surface contaminants. Livermore researchers are also developing improved computer algorithms and measurement capabilities for subsurface imaging that can be applied to improve environmental management. In addition, we are examining emission-free, high-temperature means for treating and disposing of nuclear wastes that contain actinide elements (including nuclear materials).

These research and development activities are relevant and contribute to projects to remediate groundwater at the Hanford, Savannah River, and Idaho sites as well as the Laboratory's Site 300. We seek to expand our funding from the Environmental Management Science Program by submitting future proposals for pursuing innovative research ideas that build on the Laboratory's special capabilities and address complex-wide environmental issues.

Radionuclides in the Environment. We are building on our basic research on contaminant movement in the vadose zone, our advanced subsurface imaging technologies, and our terascale computing expertise to greatly improve capabilities to characterize and mitigate in situ radionuclide contaminants. A better understanding of subsurface science—together with improved measurement and simulation tools—will help guide environmental management decisions and validate long-term environmental compliance. Moreover, improvements in characterization and mitigation techniques offer the possibility of dramatically reducing the cost and time required to control radioactive contamination and achieve closure of contaminated DOE contractor sites.

Faster Remediation Technologies. To reduce environmental cleanup costs within DOE and nationwide, we will develop and implement accelerated remediation technologies, which will not only reduce the cost of cleaning up subsurface contamination but will also allow land to return to productive economic uses more quickly than previous methods. Our strategy will be to target DOE, DoD, and civilian contamination problems as opportunities for technology development and application. To validate the performance and the economics of our technologies for other federal and commercial cleanup sites, we will continue building working relationships with industry and regulators on small and large scales and develop the engineering and economic bases for advanced remediation technologies.

Improvements to ARAC. ARAC functions as an integrated research, development, and operational program at the Laboratory. We continue to modernize ARAC's capabilities to better meet the needs of current and potential customers and facilitate services to them. For example, we have developed and continue to improve Web-based network communications to the ARAC central system. During an actual event, this Internet Remote Access capability allows simultaneous access by multiple emergency response agencies to ARAC's incident characterization and assessment products.

In addition, national security concerns have expanded beyond the nuclear threat to include chemical and biological releases. Potential ARAC applications range from accident response to countering terrorism threats. We are coordinating ARAC research efforts with DOE's Chemical and Biological Nonproliferation Program and developing the capability to predict the fate of chemical or biological releases both outdoors and indoors (for example, in buildings and subways). Our focus is on the prediction of airflow and dispersion in difficult-to-model urban environments. In particular, we are developing an ARAC interface to Livermore's very high-performance computers to provide real-time local meteorological and dispersion forecasts, detailed vulnerability and mitigation assessments, and accurate predictions of the dispersion and fate of chemical or biological agents released into a complex urban environment. Our goal is the capability for planning, training, and ultimately, emergency-response assessments of urban chemical and biological releases.

Fuels Assessment. Transportation fuels are a crucial component of the economic infrastructure of the U.S. However, they pose health and environmental risks that regulatory agencies, as well as the auto and oil industries, have had difficulties in predicting and managing. For example, the health and environmental effects associated with the use of tetra ethyl lead and, recently, methyl tertiary butyl ether, were never properly assessed before their introduction to the market. Such assessments are inherently complex and multidisciplinary and cannot be completed in any coherent fashion by multiple organizations with different missions.

Working with collaborative partners, including links to the oil and automotive industries, Livermore can provide the needed expertise to advance methodologies for science-based analyses of fuels and fuel additives. Livermore has the technical capabilities to assess the health and environmental consequences of the entire life cycle of a given fuel or additive—its production, distribution, storage, and use. For each step in the life cycle, capabilities are needed to quantify the contaminant releases, characterize the transport and evolution of the fuel-related substance in the environment, and assess the potential health and ecologic risks.

3.2 Bioscience and Biotechnology

Livermore's bioscience program has grown out of a long-standing biomedical research mission to identify and characterize the effects of ionizing radiation on human health, which led to the development of sensitive instrumentation for genomics research. Today and in the future, research activities in biology, biotechnology, and health care fit well in a technology-rich, multidisciplinary, broad-based national laboratory. The core program in biosciences is multidisciplinary, drawing upon Livermore's matrix organization in physical sciences and engineering. Many bioscience program staff are physicists, chemists, engineers, mathematicians, and computer scientists who are brought in from the diverse laboratory infrastructure and who work side-by-side with the core biologists and biochemists.

Working with academia, government, and industry, we leverage the Laboratory's capabilities in the physical and engineering sciences to conduct bioscience and biotechnology research of national importance. Livermore is part of an accelerating revolution in biology and biotechnology. The groundwork for this revolution was laid in the 1980s with a shift of the national research strategy toward large-scale, complex projects, notably the Human Genome Project. This project, in which Livermore is a significant participant, is creating material resources, technologies, and information to set the stage for dramatic advances in the 21st century.

The cross-fertilization of talents provides our bioscientists access to the latest technologies in physical sciences and engineering inherent in the parent discipline organizations. Conversely, bioscientists at Livermore make significant contributions to national security activities and other major programs at the Laboratory. For example, detection technologies developed at Livermore are used to monitor and characterize biological weapon proliferation activities and to respond in the event of an emergency. This important "spinback" to the Laboratory's defining mission increases the benefits to the nation of sustaining a strong bioscience and biotechnology program at Livermore.

Grand Challenges in the Biosciences. Four challenges have been identified that align with DOE's and the Laboratory's missions and draw upon our existing personnel talents and core competencies:

• Genomics. Learning how living systems function and using that information to enhance our nation's security, preserve the environment, and ensure a better quality of life.

• Biological Nonproliferation. Providing new, more sensitive tools for the rapid identification, isolation, and characterization of potential pathogens.

• Disease Susceptibility: Identification and Prevention. Determining what causes disease, why some people are more susceptible than others, and what we can learn to prevent it.

• Health Care and Medical Biotechnology. Developing tools for cost-effective, high-quality health care for our nation.

Bioscience and biotechnology research at Livermore is supported by diverse sources. Support from the DOE Office of Biological and Environmental Research (OBER) is about 50 percent of the overall budget. That office supports major research efforts at Livermore as well as Joint Genome Institute activities at our Walnut Creek location. Our focus remains on serving the needs of OBER and developing with them new program opportunities.

Additional support comes from sources such as the National Institutes of Health (NIH), other government sources, and industry. The NIH is the major funding source for bioscience research in the U.S., and funding from this agency is expected to continue growing. NIH and peer-reviewed funding is essential for Livermore bioscientists to maintain credibility with their peers. Bioscience researchers from Livermore and the University of California at Davis Medical Center jointly have applied to NIH to be designated as a National Cancer Institute comprehensive cancer center. Finally, with funding from multiple sources, the Laboratory enriches the biosciences research program for DOE, and we can apply the Laboratory's special science and engineering skills to meet the important needs of a variety of sponsors.

3.2.1 Genomics

Situation and Issues

Genomics Research. Genomics is a multidisciplinary science whose goals are to characterize the genetic material of mammalian, plant, and microbial species. Research efforts include studies of genome organization (examination of the interposition of genes with structural and regulatory elements in DNA), identification of genes, determination of gene expression and function, and prediction of the proteins that genes produce. Comparative genomics (cross-species analysis) is an important method to study evolution, gene function, and human disease.

The enabling technologies for genomics research include physical mapping, DNA sequencing, gene discovery, methods to measure gene activities such as a microarray, computations and informatics, and automation and robotics. The ability of DNA sequencing to serve as a unique identifier of species or individuality is relevant to this effort. In particular, Livermore's Genome Center has been at the forefront of DOE's efforts to advance the needed technologies and perform accurate, high-throughput DNA mapping and sequencing of the human genome. The portions of the center focused on DNA sequencing merged in recent years with the two other DOE genome centers at Berkeley and Los Alamos national laboratories to create the DOE Joint Genome Institute (JGI). By pooling efforts, the three DOE centers have produced a state-of-the-art sequencing facility, presently capable of sequencing more than 30 million raw bases per day. Because of this capacity, JGI was one of five centers (the G5) that were recognized as major contributors to the recent completion of the human draft genome sequence. JGI's efforts are now focused on finishing the sequence of human chromosomes 19, 16, and 5 by 2003. In addition, JGI has sequenced substantial portions of the genome of the mouse, pufferfish, and a primitive chordate, Ciona, as tools for evolutionary and functional annotation of human sequence; and JGI has completed the sequence of a number of microbes of specific interest to DOE.

In addition to our work with JGI, we are working with universities and other research institutions to provide a comprehensive public collection of complementary DNA (cDNA) clones. The DOE-sponsored I.M.A.G.E. Consortium, based at Livermore, includes over 2.3 million arrayed clones, 1.9 million sequences, and over 50,000 mapped cDNAs. We are also building new technologies to study human gene regulation and function using the mouse model system, and we are applying genomic approaches to study diversity, virulence, and gene regulation in microbial pathogens.

Program Thrust

Joint Genome Institute. We are providing the technical and managerial support required for JGI to succeed in its ambitious goals. In partnership with Lawrence Berkeley and Los Alamos national laboratories, we have implemented a strategy for production-mode DNA sequencing. Central to this production mode is the operation of a

DNA sequencing facility in Walnut Creek, California. Continued success in production sequencing also depends on an effective program of new technology development, which will make efficient use of the laboratories' capabilities as well as external sources. In particular, Livermore's expertise in engineering and the physical sciences will be applied to develop new instrumentation, automation, and integrated robotics systems to minimize human intervention, reduce error, and reduce costs. With the completion of the draft sequencing of three human chromosomes, JGI is expanding efforts into production-scale comparative and functional genomics. Livermore is contributing to the future of JGI and DOE's post-genomics program by developing new technologies and strategies for functional genomics—including methods for measuring gene expression, experimental and computational tools for human and microbial sequence annotation, protein-folding prediction tools, and the first steps toward understanding the components of gene regulatory pathways from microbes to humans.

JGI provides immediate and full public data releases and relies on Livermore's unique computing and bioinformatics expertise to provide for analysis, storage, and networking of data.

3.2.2 Countering Biological Terrorism

Situation and Issues

With a foundation of broad bioscience and biotechnology research, we are able to quickly respond to the national call for basic and applied research in countering possible biological terrorism. Since 1991, we have been researching certain elements of molecular biology with the goal of developing, analyzing, and synthesizing molecular information regarding potential biowarfare agents. Researchers at Livermore have actively focused on the foundational biology needed for this important program.

Program Thrusts

Microbial Studies. We couple our technologies and competencies in the national security area (e.g., biological nonproliferation and counterterrorism) with those in the biological sciences (e.g., microbial genetics, enzymology, and genomics) and in engineering (e.g., microfabricated bioinstruments). Applications relevant to national security include the detection and biological signature analysis of samples collected from air, soil, or water. Specific applications of genomic technologies support our national security, energy, and environmental programs. Of interest are methods and resources to identify species within the animal, plant, and microbial communities for use in forensic, bioremediation, or biodiversity applications. Such methods might be DNA- or antibody-based, but new technologies are also sought. Important to these methods are automated approaches for scale-up, miniaturization, and multiplex analysis.

Technology Development. Livermore researchers have joined with colleagues at Los Alamos, Brookhaven, and Sandia national laboratories to develop a five-year research plan that will expand the four laboratories' research in the areas of DNA-based "fingerprint" signatures, structure-based attribution, and molecular epidemiology. Several underlying technology development efforts will support these three general areas. These include (1) rapid identification, isolation, and characterization of unique DNA; (2) characterization of microbial backgrounds; (3) characterization of signatures of genetic engineering and virulence factors; and (4) baseline genomic sequencing of selected pathogens. Each program element is designed to the specific support program objectives of providing warning of any biological warfare attack, characterizing the nature and extent of such an attack, and providing forensic evidence to aid in identifying and prosecuting perpetrators. These same tools will have strong spinoff benefits for the development of vaccines, drugs, and other medical treatments as well as for environmental bioremediation.

3.2.3 Disease Susceptibility Identification and Prevention

Situation and Issues

Disease and Genes. The focus of research in disease susceptibility and prevention is the relation between an individual's genes and disease. Cancer and other human diseases are often caused by defective proteins or damage produced by radiation or by molecules that bind to and alter DNA. To understand the structure of proteins and defects in the structure, we must rely on high-resolution experimental methods and computational modeling of the molecules.

Research at Livermore already has led to identifying the genetic causes of a number of diseases, such as two forms of dwarfism. Other efforts have led to a clearer understanding of the role of cooked food (food mutagens) in genetic changes and cancer. In these activities, we draw upon existing capabilities at the Laboratory, including cloning, gene expression, biophysics and structural biology (crystallography, x-ray diffraction, and nuclear magnetic resonance), analytical chemistry (biological accelerator mass spectroscopy), computational biology, and bioengineering.

Program Thrust

Gene Identification. Our goals are to identify genes that control individual susceptibility (with emphasis on DNA repair genes), understand how the associated proteins might be involved in the disease process, assess human variability for these genes, and estimate risk for disease on the basis of an individual's genetic constitution. We will couple this research to genomic approaches, which should expedite rapid discovery. A special focus area will continue to be risk assessment of ill health from adverse exposure to radiation and chemicals, either directly through human studies or through cellular and animal data.

Livermore maintains state-of-the-art x-ray crystallography and nuclear magnetic resonance facilities, for both our own research and external collaborations, as well as a protein structure prediction center for the scientific community. We will develop new molecular, instrumentation and computational methods that will allow the genome of any organism to be scanned and analyzed quickly for gene content and function. By coupling biophysical measurements of protein structure with computational approaches for protein folding and function prediction, we may be able to link gene and protein information to measure genetic variation and biochemical function in humans. These efforts will take advantage of the unique high-speed computing capabilities at Livermore.

3.2.4 Health Care and Medical Biotechnology

Situation and Issues

Cost-Effective Technologies. Affordable, accessible health care has become an issue of national importance. Each year in the U.S., about 14 percent of the gross domestic product is spent on health care—about $3,000 for every American. Livermore researchers are working to develop more cost-effective health-care technologies. Projects exploring improved or new health-care technologies evolve at Livermore from diverse research efforts, in many cases applying or adapting technologies, devices, and processes that were developed for our national security mission. Livermore efforts are already having an effect on the frontiers of research and in the treatment of such maladies as cancer, heart disease, stroke, diabetes, osteoporosis, and repetitive strain injury as well as such specialty fields as ophthalmology and prosthesis design and manufacture. The ultimate goal of such work is to transfer new, cost-effective devices to industry for manufacture.

Our efforts are usually multidisciplinary and often involve external collaborators. We work closely with health-care deliverers and industry to develop and demonstrate novel health-care technologies, such as high-tech tools to aid stroke treatment. Increasingly, industry is expressing interest in partnering with and funding development activities. We benefit from our proximity to the San Francisco Bay Area's biotechnology firms, many of which lead the country in research.

Program Thrust

Device and Method Developments. One component of a newly proposed NIH Comprehensive Cancer Center (a joint project of Livermore and the UC Davis Medical Center) focuses on the development of specific medical devices of interest to the medical community. Current major application areas include medical device development for diagnosis and treatment of stroke, radiation treatment planning, and patient monitoring. Projects combine the Laboratory's expertise in sensors, imaging, computational physics, informatics, microfabrication, and lasers with university and industry knowledge in biomedicine. For example, Livermore is developing novel methods and surgical tools for the treatment of stroke. We have adapted physics simulation capabilities into a unique planning tool (PEREGRINE) for radiation treatment of cancer, which could help the more than 350,000 Americans diagnosed each year with a curable form of cancer.

3.3 Fundamental Science and Applied Technology

One of DOE's primary missions is to pursue fundamental science and provide capabilities that enable the U.S. to maintain its world leadership in science. The Department must also advance the science and technology that is required to support DOE's primary missions in national security, energy resources, and environmental quality. It is widely recognized that the nation's advances of fundamental knowledge and technological innovation provide the U.S. an advantage in an increasingly competitive world.

The pursuit of fundamental science and the advance of applied technology go hand in hand at Livermore. State-of-the-art applied technology is used to advance fundamental science in areas pertinent to the Laboratory's major missions. In some cases, the work is sponsored by DOE's Office of Science or other customers who take advantage of the unique research capabilities and facilities present at the Laboratory. In other cases, the work is supported by

Laboratory Directed Research and Development funding and extends Livermore's capabilities in support of current and new mission requirements.

Our scientific advances—and technologies developed in pursuit of fundamental science—have important spinoff and spinback applications, such as:

• Livermore-developed adaptive optics technologies that have been installed on the 10-meter-diameter Keck II Telescope on Mauna Kea, Hawaii, to correct for atmospheric turbulence and significantly improve the quality of images—surpassing those from the Hubble Space Telescope. Adaptive optics is also a critical, enabling technology for the National Ignition Facility.

• The discovery of fluid metallic hydrogen—a new state of matter—which contributes to planetary science and generates new knowledge about the properties of hydrogen that is needed for Laboratory programs.

• Livermore's development of ultra-short-pulse lasers, which enable physics experiments at plasma conditions similar to those inside stars. The lasers also have precision cutting capabilities for advanced manufacturing in stockpile management and many broader applications where distortionless processing is required.

• Experiments using Livermore's diamond anvil system to study the equation of state of carbon dioxide at extreme conditions. Researchers have created solid forms of carbon dioxide never before seen in the laboratory, one of which (CO_2-V) has covalent bonds and shows nonlinear optical behavior. The work generated data needed to improve simulation codes used for stockpile stewardship and resulted in three papers in *Physical Review Letters* and an article in *Science*.

• Materials synthesis and materials engineering at the atomic level. For example, we have developed ultraprecise grating arrays for spectrometers for the X-Ray Multi-Mirror Newton Observatory and multilayer optics that enable mapping the x-ray spectrum of the Sun in incredible detail.

• Studies, with the U.S. Geological Survey, to understand the equation of state of methane clathrate. The work may lead to future exploitation of methane clathrate as an energy source and of a clathrate from carbon dioxide. In addition, if carbon dioxide proves to be relatively stable as a clathrate in the deep sea or in deep-sea sediments, it could be a promising option for deep-sea carbon sequestration.

• Livermore's participation in the Extreme Ultraviolet Lithography project, along with Sandia/Livermore and Berkeley national laboratories, that has achieved the critical milestones to make this the technology of choice for computer microchip fabrication over the decade 2005–2015. ASCI computers for the Stockpile Stewardship Program will, in turn, become increasingly powerful.

Science and Technology at the Laboratory

The tight coupling of science and technology at Livermore is reflected in our mission focus and the use of Laboratory Directed Research and Development to prepare for future mission requirements. As discussed in Section 3.4, we depend on effective partnerships with other laboratories, academic institutions, and industry to be successful in our endeavors.

Application of Mission-Directed Science and Technology. As an institution with stable mission responsibilities and program continuity, the Laboratory has developed a strong science and technology infrastructure. We focus our unique capabilities and research facilities on problem solving to meet the demands of DOE's national security business line. This science and technology base also enables us to meet other important national needs and respond to new challenges. These national needs align with DOE's business lines in energy resources and environmental quality (see Section 3.1 Energy and Environmental Programs) and science (see Section 3.2 Bioscience and Biotechnology and Section 3.3.1 Application of Mission-Directed Science and Technology).

Laboratory Directed Research and Development. We sustain and strengthen the Laboratory's science and technology base through effectively managed internal investments in Laboratory Directed Research and Development (LDRD). LDRD supports research and development (R&D) projects that enhance Livermore's core strengths, expand DOE's and the Laboratory's scientific and technical horizons, and create new capabilities in support of the Laboratory's missions.

Alignment with the DOE Strategic Plan

The strong interrelationship between science and technology at the Laboratory means that technology development is integral to our programmatic activities and serves as a principal tool for achieving mission success. This approach is reflected in the *DOE Strategic Plan*, which does not specifically identify "technology" as one of DOE's four main business lines; instead, technology is appropriately distributed throughout the Department's missions. "Science" is a DOE mission, but it also is a tool for achieving mission success in other business lines.

Accordingly, some of the Laboratory's fundamental science activities are supported by DOE's Office of Science. Other activities—particularly in national security areas—are embedded in programmatic work, and yet other activities are supported by Laboratory Directed Research and Development.

DOE's science mission is to "advance the basic research and instruments of science that are the foundations for the Department's applied missions, a base for U.S. technology innovation, and a source of remarkable insights into our physical and biological world and the nature of matter and energy." Activities at the Laboratory address the four objectives of the science business line:

Objective 1: Provide the leadership, foundations, and breakthroughs in the physical sciences that will sustain advancements in our nation's quest for clean, affordable, and abundant energy. See Sections 3.1.1 Nuclear Systems and Materials Management and 3.1.2 Energy, Carbon, and Climate.

Objective 2: Develop the scientific foundations to understand and protect our living planet from the adverse impacts of energy supply and use, support long-term environmental cleanup and management at DOE sites, and contribute core competencies to interagency research and national challenges in the biological and environmental sciences. See Sections 3.1.2 Energy, Carbon, and Climate and 3.1.3 Environmental Risk Reduction.

Objective 3: Explore matter and energy as elementary building blocks from atoms to life, expanding our knowledge of the most fundamental laws of nature spanning scales from the infinitesimally small to the infinitely large. See Sections 2.1 Stockpile Stewardship, 3.2 Bioscience and Biotechnology, and 3.3.1 Application of Mission-Directed Science and Technology.

Objective 4: Provide the extraordinary tools, scientific workforce, and multidisciplinary research infrastructure that ensure success of DOE's science mission and support our nation's leadership in the physical, biological, environmental, and computational sciences. This objective is addressed by almost all of our activities. Some of our activities for DOE's Office of Science are especially emphasized in Section 3.3.1 Application of Mission-Directed Science and Technology.

3.3.1 Application of Mission-Directed Science and Technology

Situation and Issues

Livermore has special capabilities for meeting some of the nation's broader challenges in fundamental science and applied technology. These capabilities and facilities are a consequence of Livermore's overall size, the need for technologies and capabilities that do not exist elsewhere, and the fact that essential elements of our national security mission are classified. Much of the expertise necessary to support national security programs resides within the Laboratory. For example, we have capabilities to develop state-of-the-art instrumentation for detecting, measuring, and analyzing a wide range of physical events. We also have expertise to support innovative efforts in advanced materials, precision engineering, microfabrication, nondestructive evaluation, complex-system control and automation, and chemical, biological, and photon processes.

Program Thrusts

Our special capabilities are being applied to meet the nation's challenges in fundamental science and applied technology, including:

Astrophysics and Space Science. In partnership with many other scientific institutions, we make important advancements in astrophysics and space science by applying the Laboratory's special expertise in high-energy-density physics, nuclear fusion, and scientific computing. Livermore researchers participate in a wide range of observational, experimental, and theoretical activities—from the creation of supernova-like instabilities using powerful lasers to the sighting of the most distant radio galaxy and the discovery of a quasi-stellar object with one of the most luminous starbursts ever.

Astrophysics research complements the Laboratory's important stockpile stewardship responsibilities and applies Livermore's expertise in high-energy-density physics. For example, there is considerable overlap between the physical data gathered to improve the predictive capability of the Stockpile Stewardship Program and that needed to improve the modeling of astrophysical processes. The Physical Data Research Program at Livermore provides validated physical data for use in nuclear weapons simulations—and in astrophysics simulations. Through a wide range of activities, theory is combined with computer simulations and laboratory measurements to provide validated opacity and equation-of-state databases.

Livermore also makes important advances in instrumentation, as demonstrated by the development of sensors for the Clementine satellite, which mapped the entire surface of the Moon. This sensor technology has led to other advances, such as development of a revolutionary camera system and its use to discover massively compact halo objects (MACHOs). Our work on adaptive optics has enabled the Keck II telescope to take images of Neptune and

Titan of unprecedented quality. Livermore's multilayer optics are yielding extremely detailed x-ray images of the surface of the Sun, and the Laboratory's ultraprecise grating arrays for spectrometers are enabling the satellite-based X-Ray Multi-Mirror Newton Observatory to take multispectral x-ray images of other galaxies.

Accelerator Technology. The Laboratory contributes to national accelerator R&D programs with its innovative approaches to accelerator design and detector systems and its broadly based capabilities in engineering, precision manufacturing, and multidisciplinary project management. Livermore was part of the three-laboratory effort that designed and built the B-Factory at the Stanford Linear Accelerator Center (SLAC). Working with SLAC and Berkeley, we contributed across a broad range of disciplines, ranging from particle physics to precision machining.

As part of an international collaboration that includes the same tri-laboratory team, Livermore is now pursuing research and development for the Next Linear Collider (NLC). The NLC would be a 30-kilometer-long facility to explore physics beyond the Standard Model, including the study of the spectra of Higgs particles. The research and development project is patterned after the very successful B-Factory collaboration. Livermore is making significant contributions in several areas of linear accelerator (linac) technology to improve system performance and obtain large reductions in project costs. Working with SLAC, we are developing an inductive solid-state modulator that is able to produce high-power, precisely shaped pulses of current with high efficiency and high reliability. We are also providing expertise and technological capabilities in advanced manufacturing to significantly reduce the cost of precision pieces (copper cells) for accelerator structure. In addition, the Laboratory is applying its unique expertise in high-average-power, short-pulsed lasers to study the feasibility of designing a high-luminosity gamma–gamma collider as a second interaction region for NLC (or any other future linear collider). A gamma–gamma collider would open up entirely new physics complementary to the electron–positron collisions.

In addition, Livermore is a charter member of a consortium including SLAC, Los Alamos, and the University of California at Los Angeles that is carrying out research and development toward a demonstration facility, called the Linac Coherent Light Source (LCLS). Advances in low-emittance electron linacs over the past several years have opened up the possibility of unprecedented brightness in a fundamentally new kind of synchrotron light source. A free-electron laser (FEL) consisting of such a linac driving a long precision-fabricated undulator can produce monochromatic 0.1-nanometer radiation that is 10 billion times brighter than existing "third-generation" facilities such as the Argonne Advanced Photon Source. Livermore is involved in several key aspects of the project, including undulator design, low-emittance electron sources, and novel x-ray optics.

Our accelerator expertise is also being applied to important national security applications, including the development of advanced diagnostic capabilities for hydrodynamic testing. A candidate technology is the use of high-energy protons as the radiographic probe of hydrodynamic tests. We have been working with Los Alamos on the design of a machine and detectors for proton radiography. This design effort has been carried out in collaboration with DOE's High Energy Physics Program at several DOE national laboratories.

Microelectronics and Optoelectronics. The Laboratory's strengths in microelectronics and optoelectronics help us meet the demands for enhanced surveillance of aging nuclear weapons as well as for advanced diagnostics and precision target fabrication in the inertial confinement fusion program. Our expertise in thin-film processing and microfabrication technology is leading to many applications in lithography, semiconductor processing and process modeling, electronics packaging, communication and computing systems, and biotechnology. Advances have made possible microtools for health care, portable biological agent detectors, and diagnostics for the National Ignition Facility.

Advanced Materials and Materials Science. Our work in materials science ranges from fundamental research on the properties of materials to the engineering of novel materials at the atomic or near-atomic levels, which are often pursued to the stage where they can be readily manufactured. Aerogels and nano-engineered multilayer materials developed at Livermore have tremendous implications for new products and future Laboratory programs. Other advances include highly efficient energy-storage components, ultralight structural materials, tailored coatings, and novel electronic, magnetic, and optical materials.

The Laboratory's fundamental research includes work for the Office of Basic Energy Sciences (OBES) in areas such as interfaces and grain boundaries and their role in the behavior of metals and the superplastic deformation of metals and intermetallics. We also conduct fundamental research on in situ characterization of welding processes. Furthermore, OBES supports work to better understand heterointerfaces using photoelectron spectroscopy and holography, and it supports efforts in which double polarization spin measurements are used to characterize magnetic structure at the atomic level.

Through fundamental science research activities, we are improving our understanding of material deformations and radiation effects on materials. In addition, we are working to develop a basic, yet detailed, understanding of the mechanical properties of metals through the development of a multiscale model of metals that is validated by experiments. The goal is to understand dislocation dynamics that affect the strength of materials at the micrometer scale. Multiscale modeling uses the Laboratory's supercomputers and involves simulations at three length scales (atomistic, micro, and meso) with information passing from the shorter- to longer-length scales. A new 300-kiloelectronvolt, field-emission transmission electron microscope (TEM) at Livermore is the best of its kind in the DOE complex. Used to study the internal structure of materials and resolve features at the atomic scale, the TEM is one of the Laboratory's principal experimental tools for studying the properties of plutonium and validating material models.

In addition, Livermore is advancing laser shock peening, a technology to impart deep compressive stresses in metals, which has benefits for the Stockpile Stewardship Program, the Yucca Mountain nuclear waste storage facility, and a range of military and industrial high-material-stress applications.

High-Performance Scientific Computing. With the arrival of successively more powerful supercomputers at Livermore through the Accelerated Strategic Computing Initiative, we have unparalleled capabilities in scientific computing that offer the potential of revolutionizing scientific discovery. A key is their effective utilization—improvements are needed in scientific software, data management, and visualization tools. Through various collaborative efforts and for sponsors that include DOE's Office of Science, we conduct basic research in computational science in areas that support programmatic objectives. Areas of focus include high-performance computing, computational physics, numerical mathematics, algorithm development, scientific data management, and visualization.

Fusion Energy Science. Livermore conducts inertial fusion experiments and pursues advanced magnetic confinement fusion schemes using the Omega laser at the University of Rochester and, in the future, the National Ignition Facility (NIF) at Livermore. We seek to identify and make progress along the most promising path to full-scale deployment of fusion power. To establish the scientific basis of energy production from nuclear fusion is a long-standing goal at Livermore.

Our goal in inertial confinement fusion (ICF) is to demonstrate—for the first time in a laboratory setting—fusion ignition and energy gain at NIF, which is now under construction at Livermore. Demonstration of fusion ignition and energy will be conducted in parallel with a research program on fusion driver concepts (ion-beam accelerators and lasers) to meet the efficiency and repetition-rate requirements of inertial fusion power plants. In particular, for DOE's Office of Science, we are working closely with Lawrence Berkeley National Laboratory to assess and advance the technology for heavy-ion accelerators as ICF drivers for commercial fusion power generation. We are also working with the University of Rochester Laboratory for Laser Energetics on advanced technologies for laser drivers.

In the area of magnetic fusion research, the tokamak concept has been used to advance the science of high-temperature plasmas. Livermore collaborates in experimental studies centered on advanced performance and power handling for the tokamak using the DIII-D tokamak at General Atomics. In the DIII-D Program, we have the lead role in the critical area of power handling (and divertor physics in general), and we contribute importantly to the study of advanced operating scenarios.

We are also focusing attention on advanced and alternative plasma confinement concepts, such as the spheromak. The spheromak has an internal dynamo to create its confining magnetic field and is therefore a much simpler and more flexible engineering concept than a tokamak. Livermore has built and is conducting tests using a 1-meter spheromak. The Sustained Spheromak Physics Experiment (SSPX) facility was dedicated in January 1999. The SSPX is achieving high electron temperatures and generating valuable data to help improve plasma simulation codes. Our goal is to understand and optimize energy confinement in the spheromak and, if results are promising, develop a larger follow-up experiment.

In addition, we provide leadership in the use of large-scale simulation of plasmas as a very cost-effective way of carrying out fusion research. We have developed the CORSICA code, which couples various computational models (such as power input, heat loss, and magnetohydrodynamic equilibrium and stability) that proceed on different time scales. We are building on the capabilities of CORSICA to take advantage of greatly expanded computational power becoming available through ASCI. As our resources permit, we will move toward ASCI-compatible integrable code structures for magnetic fusion.

Laser Science and Technology. The Laboratory has unmatched capabilities in high-energy and high-power solid-state lasers. We will apply this expertise to meet critical needs in national security, energy security, and environmental applications. In addition, we will expand collaborations with industry and other partners to identify laser and electro-optics technologies that can be developed and transferred to the private sector.

One area of attention is the development of high-average-power ultrashort-pulse laser technology and hardware. Before the Nova laser was shut down, the Laboratory successfully developed and operated the Petawatt laser system, which still holds the world's record for the highest pulsed power ever achieved by lasers. One of the critical enabling technologies was the manufacture of large-aperture and high-damage-threshold diffraction gratings. The technology is being applied to the National Ignition Facility, and we have been developing and fabricating large-aperture diffraction optics for Work-for-Others sponsors. Researchers are also developing large-aperture lightweight Fresnel lenses for space-based applications.

In addition, Livermore scientists have built a high-average-power, high-peak-power laser (Falcon), which is being upgraded to achieve 4 joules of energy per 30-femtosecond pulse. The Falcon laser is being integrated with the 100-megaelectronvolt electron beam generated by the Laboratory's linac facility. The objective is to produce ultrashort bursts of tunable hard x rays (greater than 10 kiloelectronvolts) that can be used to make time-resolved measurements of the properties of materials undergoing rapid change. Other efforts are focusing on the development of an even shorter pulse laser that has set a world's record for brightness. The goal is to use this laser (JanUSP) to explore plasma conditions similar to those inside stars and detonating nuclear weapons by extremely rapid heating of small samples of material.

Precision-Manufacturing Technologies. The Laboratory has considerable capabilities in advanced manufacturing technologies, ranging from femtosecond-laser machining to precision manufacturing and manufacturing control. For example, the Laboratory is a world leader in precision engineering and in developing precision manufacturing systems, with technical expertise in a wide range of areas. The Laboratory has invented a number of new metrological devices in response to programs that have needed parts fabricated or measurements made beyond the limits of existing instruments. An example is the absolute interferometer, able to measure errors in the surfaces of optical parts to the thickness of just a few atoms. One of our finest achievements of precision engineering is the Laboratory's Large Optics Diamond Turning Machine, which is the most accurate large machine tool in the world.

Livermore's precision engineering capabilities support a wide range of activities—from ultraprecise optics for the National Ignition Facility and metrology for extreme ultraviolet lithography to femtosecond laser cutters for stockpile stewardship and industrial applications.

3.3.2 Laboratory Directed Research and Development

Since its inception, Livermore's Laboratory Directed Research and Development (LDRD) Program has provided support for many important and innovative scientific and technological advances. LDRD continues to play a vital role in developing new science and technology capabilities that respond to DOE and Laboratory missions and in attracting the most qualified scientists and engineers to the Laboratory. LDRD is one of the Laboratory director's most important tools for developing and extending Livermore's intellectual foundations, for enhancing its core strengths, and for driving its future scientific and technological vitality. It is an important vehicle for bringing new talent to Livermore through collaborative research and postdoctoral opportunities. Research and development that expand the horizons of science and technology are essential to the continued vitality of the Laboratory and its ability to meet future mission needs.

LDRD was established by Congress as a means for DOE laboratories to directly fund creative, innovative basic and applied research activities in areas aligned with their principal missions but not immediately supported by sponsors. In FY 2000, Livermore LDRD was funded at the allowed annual level of 4 percent, with a budget of $35 million. The 4-percent level directed by Congress in FY 2000 constituted a significant reduction of the LDRD Program. In FY 2001, LDRD funding was restored to the 6-percent level, that of previous years, with a budget of about $55 million.

A Mission Focus. LDRD funds are reinvested in the mission areas of sponsoring programs and in R&D

projects that align with the strategic vision of the Laboratory. Accordingly, Livermore's LDRD portfolio has a strong emphasis on national security. Each year, Livermore's proposed plan and requested program funding are evaluated against Congressional requirements regarding support of national security programs. Our assessments for the past four years and an estimate of the FY 2001 portfolio show national security sponsors of work at Livermore receive an LDRD return that far exceeds the investment—nearly 90 percent of the Laboratory's LDRD portfolio contributes to our national security missions.

In fact, all sponsors of research and development at the Laboratory draw a return greater than their LDRD investment. Livermore's LDRD portfolio reflects the Laboratory's focus on its special capabilities, which are applied to multiple mission areas, and on advancing those areas of science and technology to simultaneously address a number of enduring national needs. Many LDRD projects advance capabilities that are important to more than one mission area—for example, ASCI-scale computing, fundamental materials science, advanced sensors and instrumentation, ultrashort-pulse lasers, and geoscience.

Program Thrusts

Livermore's LDRD Program has three major components: Strategic Initiatives, Exploratory Research, and the Laboratory-Wide Competition. In FY 2001, about 27 percent of the funding is invested in Strategic Initiatives, about 67 percent in Exploratory Research, and about 6 percent in the Laboratory-Wide Competition.

Strategic Initiatives. Strategic Initiatives are selected on the basis of their alignment with the Laboratory's strategic directions and long-term vision. Proposals for these projects are responsive to the R&D needs of at least one of the Laboratory's five strategic councils: the Council on National Security, the Council on Energy and Environmental Systems, the Council on Bioscience and Biotechnology, the Council on Strategic Science and Technology, and the Council on Strategic Operations. Strategic Initiatives are usually more challenging than projects in the other categories and typically entail the efforts of 5- to 10-person multidisciplinary research teams.

Exploratory Research. Exploratory Research proposals are submitted by the directorates, who first review the proposals to ensure their alignment with the directorate's strategic R&D requirements. The selection process for Exploratory Research projects weighs each proposal's ability to attract and develop young scientists, maintain the scientific and technological competence of the Laboratory, further the organization's strategic vision, and reach academic and industrial communities.

Laboratory-Wide Competition. The Laboratory-Wide Competition provides all members of the Laboratory staff the opportunity to pursue their own creative ideas for one to three years. In this competition, the winning innovative projects further the missions of the Laboratory but are not required to pass a line-management filter.

Recent Accomplishments

Livermore's LDRD Program has been very productive since its inception in FY 1985, with an outstanding record of scientific and technical output. The program continues to provide many far-reaching scientific and technical accomplishments, which are described in detail in the Laboratory's LDRD annual reports (UCRL-LR-113717-00 for FY 2000).

National Security Support. The Laboratory's national security mission—stockpile stewardship of U.S. nuclear weapons and countering the proliferation of weapons of mass destruction—provides a focus for Livermore's LDRD portfolio. Representative highlights from the FY 2000 LDRD Program include:

• Proton Radiography Research. A Livermore team, in collaboration with Los Alamos scientists and engineers, is making significant progress in demonstrating the feasibility of using high-energy protons focused with magnetic lenses to radiograph thick objects that are of interest to the Stockpile Stewardship Program. The researchers have conducted tests at Los Alamos and Brookhaven national laboratories. The tests have centered on extending basic proton science and gauging proton radiography's ability to image and differentiate materials in both static and explosive situations.

• Modeling and Simulation for Critical Infrastructure Protection. Using LDRD funding, we are developing an integrated suite of simulation engines, computer visualization tools, analysis techniques, and assessment methods for understanding and evaluating issues pertinent to information security. We need improved capabilities to predict, recognize, and react in real time to potential intrusions. The complex challenges include automated characterization of computer networks, network modeling, analysis of network structure, identification of vulnerabilities, simulation of network behaviors, and assessment of the consequences of intrusion.

Awards and Recognition. Laboratory scientists and the research funded by LDRD continue to garner national recognition. For example, PEREGRINE™, a three-dimensional Monte Carlo radiation dose calculation system, received a Federal Laboratory Consortium Award for Excellence in Technology Transfer in 2000. PEREGRINE™ was initiated through LDRD. In addition, CAPS, the Counterproliferation Analysis and Planning System, which began as an LDRD project and was later funded as a Work-for-Others project, was named by the Secretary of Defense as the preferred counterproliferation tool for use by the nation's armed services. CAPS is an extensive computer database and planning tool for analysis of worldwide weapons of mass destruction capabilities and response options. Furthermore, the team that discovered element 114, including LDRD-supported researchers from Livermore and scientists from Dubna, Russia, was honored for the discovery by both *Chemical Engineering News* and *Popular Science*.

Many patents and R&D 100 Awards from *R&D Magazine* have been earned for innovative technologies developed through LDRD-funded research. In FY 2000, 35 of the Laboratory's 93 patents were LDRD-based. Since 1978, 47 of 85 R&D 100 Awards given to Livermore scientists by *R&D Magazine* have been based on LDRD research, and in 2001, one of the three R&D 100 Award winners had its origin in LDRD research.

Student Support. The participation of scholars-in-training adds vitality to the Laboratory's R&D efforts and provides a pool of talented prospects for future career scientists and engineers. LDRD projects provide valuable support for student and postdoctoral research—60 students and 95 postdoctoral fellows in FY 1999; however, there were only 33 students and 75 postdoctoral fellows in FY 2000 because of the reduction in DOE funding. Even though LDRD was restored to the 6-percent level in FY 2001, the number of postdoctoral fellows has increased only slightly, to 77, due to the difficulties in recruiting highly qualified candidates. LDRD has supported 60 students in FY 2001.

Long-Term Benefits. Because of the nature of research, many years might pass before the full impact of a research and development project is realized. Several recently funded LDRD activities achieved major successes that have been broadly reported in the scientific communities as major scientific accomplishments:

- Research leading to extreme ultraviolet (EUV) lithography. LDRD-funded research in the 1980s provided much of the basic capabilities to enable the Laboratory to be a major player in a $250-million cooperative research and development agreement (CRADA) with the leaders in semiconductor manufacturing.
- Biological weapon agent detection and identification. In a terrorist attack or on the battlefield, lives may depend on a quick determination of whether a biological agent has been used. LDRD-funded research led to the development of two highly portable and extremely sensitive technologies. Further developed under DOE/NNSA sponsorship, the Handheld Advanced Nucleic Acid Analyzer (HANAA) has dramatically advanced biodetection capabilities and now provides real-time identification of bioagents in the field.
- Environmental cleanup technologies. For many years, LDRD has funded research projects to identify better methods for cleaning up soil and groundwater contamination. The program contributed to the development of two technologies, dynamic underground stripping and hydrous pyrolysis/oxidation, that have been very successfully demonstrated in Visalia, California. These technologies are now being used for site cleanup at two major DOE facilities, the Portsmouth Gaseous Diffusion Plant in Ohio and the Savannah River Site in South Carolina.

3.4 Partnerships and Collaborations

Many Livermore research and development activities are executed in partnership with industry, academic institutions, and other laboratories. Partnerships and collaborations are often the most cost-effective way to accomplish our programmatic goals. In addition, Livermore has a responsibility to move appropriate technologies developed in the course of our mission work into the marketplace, where the advances can have the maximum positive impact on the U.S. economy or other important national priorities.

Program Thrusts

Partnerships That Create New Capabilities. Partnering has been important at the Laboratory ever since our establishment as part of the University of California and the early days of supercomputer development to meet the needs of the weapons program. Partnering will play an even more significant role in the future. Activities will continue to span a wide range—from very large-scale strategic alliances and "virtual laboratories" to licensing of individual technologies, academic research, and support for the small business community. For example, the Laboratory is one of the founding partners (with Sandia, the City of Livermore, and private-sector sponsors) of the Tri-Valley Technology Enterprise

Center (TTEC), a regional business incubator under the aegis of the Tri-Valley Business Council. TTEC is providing support for start-up high-tech companies. We also work with others to share expertise and make available research capabilities.

Effective Academic Collaborations and Science Education Programs. As a part of the University of California and as a national laboratory, Livermore shoulders significant science education responsibilities. By making the Laboratory's research facilities and staff accessible to the academic and industrial communities, we provide valuable opportunities to visiting researchers while we strengthen our science and technology base. Academic collaborations bring new science and technology to the Laboratory's national security programs and help attract and retain outstanding technical staff. We are home to several University of California scientific research institutes and other unique facilities that support hundreds of ongoing projects with faculty, postdoctoral fellows, and graduate students. We also help train the nation's next generation of scientists and engineers through our science and technology outreach programs that span all educational levels.

3.4.1 Partnerships with Industry

Situation and Issues

Livermore is committed to promoting partnerships with U.S. businesses and industries. We anticipate that the Laboratory's partnerships and alliances with industry will continue to grow. We work with U.S. companies for various reasons and use a variety of partnering mechanisms. Most importantly, we form partnerships with industry to support our national security mission. For example, our participation in a consortium to develop advanced technologies to manufacture computer chips will also enhance critical advanced computation capabilities at the Laboratory. Technology transfer also promotes economic development and national competitiveness. Finally, the areas of environmental remediation and health care provide examples where we "spin off" for public benefit Laboratory-developed technologies through mechanisms such as CRADAs and licensing.

Livermore's interactions with U.S. industry are exemplified by our 88 active licensing agreements, 47 active CRADAs, 99 industrial Work-for-Others agreements, 175 reported inventions, 112 patent applications, and 95 issued patents in FY 2001 (also see Table 3-2).

We are also involved in the new business incubator, TTEC, which will provide offices at our Livermore site, laboratory space, and administrative and management support to start-up companies. It is a prime example of the Laboratory's involvement in the community.

Livermore's Industrial Partnering and Commercialization (IPAC). This office facilitates many of our interactions with industry. IPAC provides information on licensing, cooperative research, and other opportunities for businesses to benefit from technology transfer, and it negotiates the contracts that govern these relationships.

Partnering Mechanisms and Activities

Licensing Agreements. Through licenses, Livermore grants permission for commercial and noncommercial access to reproduction, manufacture, sale, or other exploitation and use of Laboratory-developed intellectual property. As an example, exceptionally effective environmental cleanup results were achieved using the Laboratory's dynamic underground stripping technology to clean up groundwater contamination at a Southern California Edison site previously used to treat power poles with preservatives such as creosote. Dynamic underground stripping and important auxiliary technologies were licensed to SteamTech Environmental Services to perform the cleanup operations. The award-winning technology has subsequently been licensed to Integrated Water Resources Inc. of Santa Barbara, California, and Southern California Edison. At DOE's Savannah River Site, 20,000 pounds of solvents were removed from a small area—20 times more than estimated. Savannah River is now planning two large implementations, and the Environmental Protection Agency will begin a large test at the Wyckoff site near Seattle. SteamTech is conducting tests at three Air Force bases, and our three licensees are using the technology for a number of private cleanups.

Our licensing efforts include the following recent highlights:

- PolyStor Corporation, founded in 1993 by former Livermore employees, has emerged as a leading U.S. manufacturer of high-performance lithium–ion batteries for the next generation of portable and wireless products.
- In 1997, the PowerStor Company was spun off from PolyStor to concentrate on developing advanced capacitors, called supercapacitors or ultracapacitors, using Livermore's carbon aerogel technology for pulsed-power and electronic circuitry applications in multibillion-dollar battery and capacitor markets.
- MiniMed Inc., a leader in infusion systems for the delivery of insulin to diabetes patients, has been working with Livermore to adapt laser technology

used for fusion research and to develop an advanced glucose sensor to continuously indicate the sugar level. When used with an implanted pump, the two devices would essentially become an artificial pancreas. Livermore has collaborated with MiniMed since 1995 in three successful CRADAs, and a Livermore-developed technology has been licensed to MiniMed.

- The Laboratory is partnering with BioLuminate Inc., a small California business, to develop Smart Probe, a tool for detecting early breast cancer with accuracy levels comparable to biopsies but without removing tissue. Because the probe incorporates several sensor technologies, its sensitivity and specificity will be better than current diagnostics and cause less suffering for the 85 percent of patients who have breast biopsies that are negative. Preliminary clinical human trials are scheduled this year at UC Davis Medical Center. The system also has multiple potential benefits to DOE, advancing novel fiber-optic sensors and enhancing capabilities of our Medical Technology Program.
- In a licensing agreement with two companies, FlexICs Inc. and Rolltronics, a Livermore laser-based technique is being developed for producing plastic flat-panel displays. Lightweight plastic displays are likely to be rugged and cheaper to produce than the glass displays they would replace.

Partnerships through CRADAs and Work-for-Others. We also work with U.S. industry through a variety of CRADAs in which intellectual property rights are negotiated. Many CRADAs were initiated in the mid-1990s with funding from what evolved to the DOE's Technology Transfer Program (TTP). Livermore's CRADAs are increasingly either Laboratory-funded (cooperative efforts on technologies we vitally need) or funds-in projects (industry backing for cooperative efforts). In addition, we engage in industrial Work-for-Others (WFO). These agreements provide non-DOE organizations with access to highly specialized or unique DOE facilities, services, or technical expertise.

One major funds-in CRADA is a project to develop technologies to produce smaller, more powerful computer chips. Researchers from the Livermore, Sandia, and Berkeley national laboratories have formed a Virtual National Laboratory that is working with an industrial consortium including Intel, AMD, Motorola, Micron, IBM, and Infineon as major partners. Our work focuses on the use of extreme ultraviolet lithography (EUVL) as a means for etching ultrathin patterns into silicon chips. EUVL technology relies on Livermore expertise in multilayer coating technology and ultraprecision optics metrology.

In 1999, the Laboratory announced the selection of NOMOS Corporation of Sewickley, Pennsylvania, to commercialize PEREGRINE™, an improved dose-calculation system for extremely precise planning and application of cancer radiation treatment. In addition to issuing a license, we are assisting NOMOS in commercialization efforts under a WFO agreement. In October 2000, NOMOS received clearance from the Food and Drug Administration to produce and market PEREGRINE™ systems and since then has begun selling the systems to cancer treatment clinics.

We currently have active CRADAs and WFOs in fields as diverse as medical devices, advanced manufacturing, and microtechnologies. Our small-business activities also include CRADAs, technical assistance, and participation in the Small Business Innovative Research (SBIR)

Table 3-2. Laboratory interactions with industry, FY 1997–2001.

Type of interaction	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	Totals
Licenses of Laboratory patents and copyrights						
Number issued	65	36	35	41	57	234
Royalties ($M)	2.4	2.3	2.2	3.2	3.4	13.5
DOE (TTP) CRADAs						
Number active	55	15	6	1	0	–
DOE funding ($M)	19.5	5.0	2.5	0.1	0	27.1
Lab-funded CRADAs						
Number active	24	19	24	19	11	–
Lab/DOE funding ($M)	4.4	3.4	3.2	2.3	1.7	15.0
Industry-funded CRADAs						
Number active	34	28	33	30	2.8	–
Industry funds-in ($M)	17.8	29.2	34.5	21.2	19.2	121.9
Work-for-Others projects with industry						
Number active	85	90	113	99	165	–
Industry funds-in ($M)	3.4	9.1	8.1	14.5	9.6	44.7
Lab SBIR projects						
Number of awards made	3	5	2	0	0	10
Industry funds-in ($M)	0.2	0.2	0.5	0.0	0.0	0.9
Start-up companies (number)	4	3	1	3	3	14

Program and the Small Business Technology Transfer Program (STTP).

Partnerships through Procurement. Livermore has always pursued industrial partnering through its procurement strategy. To cost effectively acquire the state-of-the-art technologies needed for our major research and development programs, we continually interact with private industries to understand their capabilities and products so that we can make informed decisions.

For example, over 75 percent of the total funding for construction of the National Ignition Facility will go to U.S. companies, including high-technology firms producing optical components. In some cases, Livermore's programmatic needs actually spur the development of new businesses or new product lines in existing companies. Advances in state of the art may be developed here and transferred to a commercializing partner or developed by the company to meet our requirements in order to generate a production-scale source of equipment, instrumentation, or components for some of our larger experimental facilities.

Similarly, in the Accelerated Strategic Computing Initiative (ASCI), DOE Stockpile Stewardship computational requirements are driving computer advancements and refinements of prototype machines. The laboratories are acquiring increasingly powerful supercomputers from U.S. industry and, in turn, helping these companies ready their new products for the wider marketplace. Table 3-2 shows our interactions with industry for FY 1997 through 2001.

Honors and Awards. The Laboratory continues to be recognized for technology transfer activities. We won six R&D 100 Awards in 1999, one in 2000, and three in 2001. The awards are given annually by *R&D Magazine* for the top 100 technological achievements that promise to improve people's lives through breakthrough products and processes. Winning entries are selected on criteria that include proof of product. The winners for 2001 are:

- Lasershot Marking System. This system will use laser pulses to safely and permanently impress identification markings on metal components. Because the process does not remove material and actually increases the marked area's resistance to fatigue and corrosion failure, it is ideally suited for marking parts used in situations where safety is critical.
- Gene Recovery Microdissection (GRM). GRM is a process for amplifying DNA fixed to a medium and can be used to produce chromosome region-specific libraries of expressed genes of virtually any plant or animal species for use in functional genomic research.
- Manufacturing Laser Glass by Continuous Melting. A novel continuous melting process is being used to manufacture meter-sized plates of laser glass for the National Ignition Facility at a rate 20 times faster, 5 times cheaper, and with 2 to 3 times better optical quality than with previous one-at-a-time discontinuous processes.

In 2001, Livermore was one of only four DOE laboratories to win a Federal Laboratory Consortium Award for Excellence in Technology Transfer, recognizing "outstanding work transferring federally developed technology from the lab to the marketplace." The Laboratory won the award for its collaboration with MiniMed Inc. of Northridge, California, for work on a continuous glucose sensor for diabetes patients. The company's objective is to combine insulin delivery pumps with glucose sensors to create an artificial pancreas.

Ongoing Process Improvements. Livermore continually strives to balance the need for streamlined partnering processes against the need for adequate controls to ensure a well-managed program. We strive to achieve partnerships that will meet the needs of both the Laboratory and its partners while operating within the structures and policies of DOE and the University of California and complying with the laws governing technology transfer.

We improved our agreement processes. Our formal partnering processes begin with an intellectual property management process that has been formalized with important controls. Each month, formal invention disclosure prioritization reviews are held to ensure disclosures selected for patenting are considered within a framework of the Laboratory's strategic objectives. In addition to DOE's modular CRADA, we use model agreements for consistency in language and structure in other technology transfer agreements. Detailed process checklists also ensure appropriate coordination and consistency. Within the IPAC office, licenses are peer reviewed by at least two business specialists and by the managers for Partnership Development, Contract Compliance, and Finance prior to formal legal review. We are also vigilant about export control reviews. For example, if an export control issue surfaces during the review process, the industrial partner is sent a letter stating that the technology is export controlled and that it is the partner's sole responsibility to obtain the appropriate export licenses. To assure our program's quality, we have formal processes to ensure fairness of opportunity for all potential partners and to avoid any appearance of conflict of interest.

Other process improvements recently have been implemented in the licensing process, for example, communications that ensure the licensee's understanding of its responsibility for obtaining all necessary regulatory approvals. Increased emphasis is placed on this issue because, on account of our mission obligations, technical assistance cannot be guaranteed in our licenses. When requests are made for technical assistance, follow-up actions are carried out through a formal agreement. Additionally, an ombuds program has been established to provide an informal process for resolving disputes, and periodic surveys are conducted of license and CRADA partners as a means of incorporating improvements into our procedures.

3.4.2 Teamwork with Other Laboratories

We are working with other national laboratories to coordinate and integrate programmatic efforts to provide the best scientific and technical capabilities for the dollars invested. Livermore's collaborative activities are increasing through participation in integrated national programs, such as the Stockpile Stewardship Program and the Joint Genome Institute. Collaborations include the design, construction, and shared use of major research facilities such as the National Ignition Facility at Livermore and many other projects described throughout Sections 2 and 3.

Factors critical to the success of these team efforts include effective high-level DOE leadership, well-defined program goals and deliverables, complementary capabilities among the national laboratories, confidence in each other's commitment and performance, and a healthy competition of ideas within a collaborative framework.

3.4.3 University Collaborative Research

Individual collaborations between Livermore scientists and university faculty and students have taken place since the Laboratory was founded. Our research collaborations with university faculty and students are designed to blend basic research with applied researchers. The collaborations provide effective ways for unique Laboratory facilities and expertise to be made available to the broad U.S. research community. Table 3-3 shows Livermore's collaborations with universities from FY 1998 through FY 2000.

The University Relations Program. The Laboratory's University Relations Program encourages and expands research collaborations between Livermore and universities and other research organizations. The program contributes to the intellectual vitality of all the partners through basic and applied research collaborations. By facilitating the flow of ideas and people between institutions and by making our unique facilities and expertise available to students and faculty, we address problems that are of interest to the broad U.S. research community and that help solve complex problems of importance to the nation.

The University Relations Program also oversees the Laboratory's science and technology education efforts (see Section 3.4.4). We help train the nation's next generation of scientists and engineers through our outreach programs that span all educational levels. The Laboratory also benefits by enlarging the pool of talent and raising awareness about Livermore and its national security mission—our continuing success depends on recruiting and retaining quality staff.

Livermore–University of California Research Institutes

Several Livermore–university institutes have been established in specific subject areas, setting a focus for collaborations with the nine University of California campuses as well as with many other universities. They provide a hospitable environment for visiting students and faculty. These institutes advance the strategic goals of the Laboratory by aligning subject matter with expertise needed to execute Laboratory programs. The institutes include:

Institute of Geophysics and Planetary Physics (IGPP). The Livermore branch of IGPP (a Multi-Campus Research Unit) runs the Astrophysics Research Center, which carries out a significant research program and manages the astrophysics part of the University Collaborative Research Program (UCRP). The Center for Geosciences in IGPP promotes UC collaborative research in the earth sciences. The center's research emphasis is on the physics and chemistry of Earth, including seismology, geochemistry, experimental petrology, mineral physics, and hydrology.

Center for Accelerator Mass Spectrometry (CAMS). Processing about 20,000 samples per year with its extremely sensitive measurement capability, CAMS supports research programs that range from archaeological dating to biomedical research, and from global climate change to geology. The capabilities of CAMS are available to all qualified users under standard DOE procedures. Some 75 service contracts are currently in place with nonprofit foundations, non-DOE agencies, and private corporations.

Institute for Scientific Computing Research (ISCR). The ISCR fosters collaborations between Laboratory and academic researchers in the areas of scientific computing, computer science, and computational mathematics. These topics are central to large-scale scientific simulations for the Stockpile Stewardship Program, and in particular for ASCI. The institute is the administrative host to dozens of graduate students, postdoctoral fellows, and visiting faculty annually, and it fosters substantial collaborations that take place on UC campuses. As of FY 2000, ISCR also administers the university portion of the ASCI Institute for Terascale Simulation at Livermore.

Institute for Laser Science and Applications (ILSA). The ILSA is a center of excellence at Livermore in the areas of laser science and novel applications of high-power lasers. We focus on high-peak-power lasers, ultrahigh-speed diagnostics, and the interaction of high-energy particles with plasmas. The institute coordinates the usage of the Livermore Research Laser Facilities (LRLF) and facilitates the participation of outside collaborators. University of California campuses—principally Davis, Berkeley, and Los Angeles—are active collaborators and participants in ILSA-supported projects. Our collaborations with other universities across the country are extensive and are continuing to expand. The institute also has an important educational mission to train the new generation of researchers in laser science and high-energy-density physics.

Materials Research Institute (MRI). The MRI fosters collaborations between Livermore and both academic and industrial researchers. The goal is to help provide the Laboratory with basic science opportunities that could have potential relevance to our missions. Our main focus is currently on two areas: materials under extreme conditions, and nanoscience and nanotechnology. Recently, the MRI has developed a graduate fellowship program in energetic materials and a summer institute for computational materials science and chemistry.

Other University Interactions

Department of Applied Science (DAS). A part of the College of Engineering at the University of California at Davis, DAS has facilities at both Davis and Livermore. It offers a limited number of temporary positions to selected UC Davis graduate students who then work in one of the Laboratory's major research facilities while conducting thesis research related to the programmatic research. In 1998, after a comprehensive review of the UC Davis DAS program, the Livermore student fellowship program was broadened beyond applied science and computer science to include all relevant UC Davis departments.

University of California Directed Research and Development (UCDRD). Other collaborative activities among the three UC-managed DOE national laboratories are supported by two funds established by the UC/DOE management contract. The UCDRD fund is available to support research activities at the discretion of each laboratory director. Livermore uses UCDRD funds for strategic investments at the Laboratory and for integrating support with other UC collaborative efforts. The Complementary and Beneficial Activities (CBA) Fund was established specifically to support collaborative research efforts through the Campus–Laboratory Collaborations (CLC) Program and the newly

Table 3-3. Laboratory–university collaborations FY 1999–2000.[a]

Type of collaboration	FY 1998	FY 1999	FY 2000[b]
Collaborations with University of California			
Total number	647	623	533
UC faculty	232	221	177
UC research staff	113	90	73
UC students	302	312	283
Collaborations with other California universities			
Total number	205	196	120
Faculty	82	84	40
Research staff	29	20	11
Students	94	92	69
Collaborations with non-California universities			
Total number	713	742	618
Faculty	309	358	253
Research staff	126	117	105
Students	278	267	260

[a]University and college faculty, research staff, and students involved in collaborative work programs with the Laboratory at Livermore, at their home institutions, or both. Numbers for FY 2001 will be available after January 2002.

[b]Differences in numbers compared to previous Institutional Plans are explained by the following:

- FY 1998 and FY 1999 data have been revised with updated information.

established Campus–Laboratory Exchange (CLE) Program.

The CLC is a multidisciplinary, multilocation research program that funds three-year projects to address complex issues that have significant social and economic impact on California. Eligible participants are scientists from all UC campuses working in partnership with researchers from Los Alamos or Livermore national laboratories. Similarly, the goal of the program is to enhance and facilitate collaboration among the nine UC campuses and the laboratories. The program supports the exchange of people between the campuses and the laboratories.

Lawrence Livermore Fellowships. Among the research opportunities offered by the Laboratory is the Lawrence Livermore Fellowship, a distinguished postdoctoral program established in 1998. The fellows have world-class resources to support their research. Fellowships are awarded only to candidates with exceptional talent, credentials, scientific track records, and potential for significant achievements. The fellows are expected to do original, independent research in one or more aspects of science relevant to the competencies of the Laboratory.

Sabbatical Program. The Lawrence Livermore Sabbatical Program was initiated in FY 2001 to encourage faculty in leading universities worldwide to spend their sabbaticals at the Laboratory. The program has three major objectives: to provide faculty access to new scientific or engineering expertise in Laboratory programs, to familiarize Livermore's new visiting faculty with our mission and capabilities, and to enhance existing relationships so that these faculty members return to their campuses as ambassadors who promote the recruitment of future Livermore employees among their students. Selected faculty are strongly encouraged to include postdocs or graduate students in their sabbatical programs. Six faculty were selected to participate for the first year of the program.

The Research Collaborations Program (RCP). Livermore's Research Collaborations Program for Historically Black Colleges and Universities (HBCUs) and other Minority Institutions (MIs), is a Laboratory-wide program. The RCP develops and promotes productive and mutually beneficial scientific collaborations between accomplished faculty and students from these institutions and Laboratory principal investigators in areas of core competency. The program provides unique research opportunities for participants and provides the Laboratory additional expertise and staffing for basic research efforts.

University of California at Merced

The University of California is developing plans to open a tenth campus in Merced, California, in 2004. The new campus, which will eventually serve 25,000 students, plans to have a close affiliation with Lawrence Livermore. UC Merced will be the first American research university built in the 21st century. In October 2000, a Memorandum of Agreement was signed by principals from UC Merced, Merced Community College, and the Laboratory to create academic partnerships among the three institutions.

UC Merced planners meet with senior Livermore managers on a wide range of issues. We are helping to establish this new campus by: contributing to the definition of scientific and engineering programs at the campus, consulting on the physical plant (e.g., energy efficiency, waste management), helping plan the programs for UC Merced's Sierra Nevada Research Institute, and serving on search committees for senior staff. Once the new campus is in operation, UC Merced and the Laboratory expect to collaborate on research projects, student internship programs, and joint appointments that will provide opportunities for Livermore personnel to teach. Over time, we expect UC Merced to become an important source of future employees for the Laboratory.

3.4.4 Science and Technology Education Program

The Laboratory's Science and Technology Education Program (STEP) serves as a resource to students, teachers, and faculty by facilitating research interactions with Livermore's world-class scientific facilities and staff (Tables 3-4 and 3-5). STEP also supports the science educational needs of the local and regional communities surrounding the Laboratory. STEP leads our science education activities, which are directed toward:

- Facilitating research internships for college students entering careers important to the intellectual capability required by the Laboratory's national security mission.
- Enhancing science literacy and science education activities through technical partnerships with the K–14 education community.

The common theme of our science education effort is the integration of education, research, and career options at all school levels—pre-college, undergraduate, and graduate school—through Livermore-sponsored projects. STEP's "school-to-career" education projects make an important long-term contribution to national security. The program further benefits the nation by helping the U.S. to compete successfully in the world marketplace and remain a major economic power. For more information about activities and annual reports, see the STEP Web site at http://step.llnl.gov/.

College Student Research Internships

STEP facilitates partnerships and collaborations with the education community to help ensure a highly skilled, diverse workforce for the science and technology challenges of the Laboratory's national security mission. During FY 2001, 117 college, university, and academy students participated at the Laboratory (Table 3-4).

The majority of stockpile stewardship internships is funded directly by NNSA/Defense Programs Office of University Partnerships (DP-OUP). Individual interns are recruited to support the specific needs of Laboratory programs, such as terascale simulation supporting ASCI.

STEP's internship projects target undergraduate and graduate college students in four major disciplines: currently targeted "critical skills" in chemistry and materials science, computer science, engineering, and physics. For example, STEP partners with various Livermore program elements in stockpile stewardship, such as high-energy-density physics, to develop recruiting programs aimed at specific college students.

STEP also works with our National Security Office to provide internship opportunities for U.S. military academy cadets, midshipmen, and college ROTC students to contribute to common mission goals between DoD and DOE.

Science Outreach and K–14 Educator Partnerships

Through local and regional education partnerships, STEP leads the Laboratory's education efforts to stimulate greater interest in science and technology among teachers and school administrators and to encourage students to pursue scientific and technical careers after high school. The science outreach and educator projects are funded by the Laboratory's General and Administrative (G&A) Distributed Budget.

Pre-college science literacy activities play an important role in the creation of future scientists, engineers, and technicians by enlightening students about potential careers in science and technology, especially those of special interest to the Laboratory. STEP's K–14 partnerships with the education community are aligned with new science standards of the State of California.

By providing a continuous school-to-career "roadmap" for pre-college, undergraduate, and graduate students interested in science and technology, STEP will continue to offer intriguing opportunities to further students' careers in science research through hands-on internships, projects, and partnerships.

STEP's science outreach and educator projects during FY 2001 engaged approximately 1,200 teachers (about 10 percent from community colleges) and 9,500 students (Table 3-5). Many of the K–14 projects are described on the STEP Web site (http://step.llnl.gov/) on its educator resources and education outreach links.

3.5 Work-for-Others

The Laboratory pursues research and development for federal sponsors other than DOE, state agencies (particularly California), and in some cases, for private industry through funds-in CRADAs. These activities are mutually beneficial to the work sponsor and the Laboratory, as depicted by the diagram that illustrates our mission statement (see Figure 1-1). Livermore's special capabilities (skills and facilities) meet

Table 3-4. FY 2001 STEP national security college student internship projects and participation.

Partners and STEP internships in national security projects	Number of interns
NNSA/DP–OUP	
Accelerated Strategic Computing Initiative (ASCI) Pipeline	12
Actinide Sciences Summer School	6
Interns for Defense Technologies	20
Internships in Terascale Simulation Technology	27
System Administration Computer Support	6
Livermore's Defense and Nuclear Technologies Directorate	
High-Energy-Density Physics Program	21
Livermore's National Security Office	
Military Academic Research Associates (MARA)	21
Reserve Officer Training Corp (ROTC)	4
Total	**117**

the special requirements of the work sponsors, and the projects are supportive of the principal mission thrusts of the Laboratory and enhance the capabilities needed to perform these missions.

Because a principal feature of the Work-for-Others projects is that they are synergistic with major missions at Livermore, each Work-for-Others project is managed by the directorate at the Laboratory that is the source of expertise and technically responsible for the work.

Department of Defense. On an ongoing basis, the Laboratory participates in approximately 250 individual projects in support of DoD programs. Some of these efforts support particular DoD needs and requirements that can best be achieved using Livermore's capabilities and expertise. Many constitute technology development and application efforts for which the results are of direct interest and benefit to both DoD- and NNSA-sponsored programs at the Laboratory. The total Laboratory budget for DoD and defense-related work was over $75 million in FY 2001.

Section 2.2 highlights our work to stem the proliferation of weapons of mass destruction, and Section 2.3.1 discusses our other principal areas of focus.

Other Federal Agencies. The Laboratory's work for other federal agencies largely entails projects for the National Aeronautics and Space Administration (NASA), the National Institutes of Health (NIH), and various intelligence organizations. The diverse portfolio of activities for NASA, which builds on special competencies at Livermore, comprises four general areas: advanced detector development, theory and computational models for analysis of spectral data from satellite missions, laboratory experiments to test theoretical spectral models, and observations and analysis (see Section 3.3.1). Similarly, our work for NIH includes a wide variety of projects that take advantage of Livermore's special capabilities (see Section 3.2). For example, the Center for Accelerator Mass Spectrometry (CAMS) is being made available to biomedical researchers who need this accurate tool to measure very low levels of carbon-14. NIH is providing funding to make CAMS a designated National Resource for Biomedical Accelerator Mass Spectrometry.

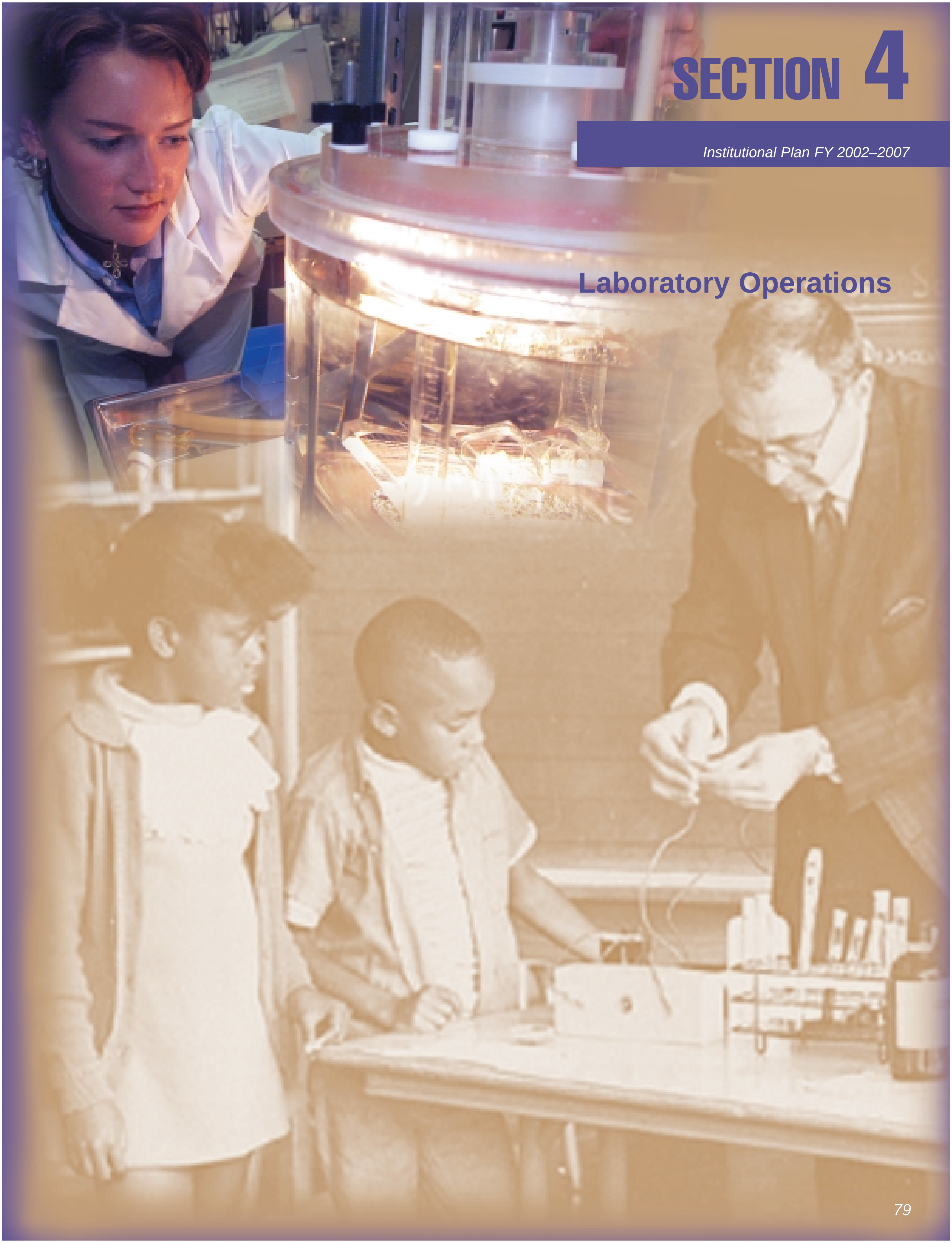
Non-Federal Work-for-Others. The Laboratory conducts nearly $40 million of research for industry, state agencies, foundations, and local governments. With a few exceptions, these projects are typically small and of short duration. Our work with industry, which includes CRADAs and licensing agreements, is discussed in Section 3.4.1.

Table 3-5. FY 2001 STEP science outreach and education projects.

Science outreach (K–12 students)	Number of participants
COSMOS (UC program)	12
Crystals in the Classroom	90
Expanding Your Horizons (3 conferences)	1,400
Explorer Post	50
Fun with Science	5,700
Future Scientists and Engineers of America	75
Groundwater Assessment Course	60
Math Challenge	50
Optics and Lasers Course	60
Science on Saturdays	1,700
Student Research Academy	12
Tri-Valley Science and Engineering Fair	250
Approximate total	9,500
K–14 Education (teachers)	
Crystals in the Classroom (teacher development)	2
Educational Partnerships	400
Edward Teller Science Education Symposium	120
GEMS Great Explorations in Math and Science	150
Computer Technology Workshops	300
Laser Science and Optics in the Classroom	30
Promoting Achievement through Hands on Science	60
UC/Community College/Central Valley Education	120
Approximate total	1,200

SECTION 4

Laboratory Operations



LABORATORY OPERATIONS

IN all Laboratory operations, we strive to set a standard of excellence in environment, safety, and health; security; and business practices among high-technology applied research and development institutions. These factors are the underpinnings of success for all Livermore programs.

The importance of quality operations and administration to the success of the institution is reflected in significant high-level organizational changes made by Director Tarter in early 2001. Three new directorates were created—Safety, Security, and Environmental Protection; Administration; and Laboratory Services—and in May 2001 associate directors were appointed to lead the new organizations. The change ensures high-level attention to important Laboratory operational issues while lessening line-management responsibilities in the Director's Office. The Deputy Director for Strategic Operations will have greater opportunity to focus on broader, more strategic issues and nurture effective working relationships with the new management teams at National Nuclear Security Administration (NNSA) and the University of California.

The Laboratory's operations serve many customers—the technical programs, sponsors, Congress, Laboratory employees, and the local community—to name just a few. To best meet the diverse, occasionally conflicting needs of these customers, the Laboratory takes an integrated approach to operations and balances attention to technical capabilities, services, and infrastructure in a way that best supports our overall objectives. Five overarching strategies reflect Laboratory priorities for operations.

Safety the Top Priority

Livermore has implemented DOE's Integrated Safety Management System (ISMS) throughout our workforce, both onsite and offsite. With DOE's seven guiding principles and five core functions as the foundation, ISMS establishes the basis for work authorization at the Laboratory. The introduction of ISMS at the Laboratory is affecting a cultural change through which operations will be carried out in the most efficient and productive manner possible under the existing umbrella of Work Smart Standards.

ISMS is integrated into all levels of work, including procured services. Operational support organizations receive training to assist the responsible individuals who are performing the work, and they in turn are trained to implement the ISMS principles.

A Commitment to Strengthened Security

The events of September 11, 2001, reinforced the prime importance of security at the nuclear weapons laboratories. Since 1999, Livermore, Los Alamos, and Sandia national laboratories have been working closely with the Secretary and other DOE and NNSA managers to tighten security and establish a baseline for an even more integrated approach to security.

We have increased our investments in security to ensure compliance and to adjust to new security threats and challenges arising from rapid changes in information technologies. In particular, we are providing even greater protection of critical assets at Livermore and implementing state-of-the-art cybersecurity, and we expanded our counterintelligence program.

Additional investments will be needed in response to the terrorist attacks in New York, Washington, DC, and Pennsylvania. To that end, we are taking steps to further increase physical and cybersecurity and security awareness at the Laboratory.

In January 2000, the NNSA laboratories and the University of California Office of the President began work on developing an approach for implementing Integrated Safeguards and Security Management (ISSM). ISSM will integrate safeguards and security into management and work practices at all levels so missions are accomplished securely.

An Emphasis on Teamwork

Since the founding of the Laboratory by E. O. Lawrence in 1952, team science—the ability to respond to challenges by forming multidisciplinary teams to get the job done—has been one of Livermore's key strengths. Teamwork is a broadly applied principle at the Laboratory—using a matrix management system to focus scientific and engineering talent where needed and integrating operational support with programs to achieve mission success. To seamlessly integrate Laboratory operational support with programs, staff and systems must be flexible, agile, and cost effective, adding value to Livermore's technical work. Many critical aspects of smooth and effective Laboratory operations, such as safety, security, and environmental protection, are every employee's responsibility.

Strategic Institutional Investment

Livermore's achievements are the product of dedicated, high-quality efforts of all employees. As a consequence, attention to workforce recruitment, training, and retention is critically important. Investments in people are investments in Livermore's future. The Laboratory supports training, education, and career development programs for individuals that meet their needs for growth and are consistent with Laboratory goals. We must ensure that employees have the best skills, training, and tools to accomplish their current work and to prepare for future assignments.

In addition, the Laboratory has been reinvesting to meet specific objectives directed at strengthening the Laboratory's scientific and technical base, meeting critical infrastructure and facility needs, and realizing long-term cost savings through one-time investments anticipated to have high return-on-investment ratios. Specific areas pertaining to Laboratory operations, such as facilities maintenance, have been identified as high-priority items for institutional reinvestment. The reinvestments have been made possible through the implementation of a well-defined initiative to streamline business practices, improve information management, and outsource services when practical and cost effective. The result has been about a 30-percent reduction (inflation adjusted) in traditional General and Administrative (G&A) costs since FY 1993, and we continue to look for ways to obtain further cost reductions to benefit Laboratory programs and enable the institution to meet strategic reinvestment needs.

Use of Performance-Based Management to Improve Operations

In 1992, the University of California (UC) and DOE pioneered a contracting approach that integrated performance-based requirements into the contract for managing and operating the three UC laboratories. Performance-based management is contributing to improvements in Laboratory operations in several significant ways:

• Benchmarking to understand norms and improve performance measures. Across almost the entire spectrum of operational activities, we are benchmarking our performance with that of other research and development laboratories to find ways to better gauge performance and identify specific areas that warrant improvement.

• Use of performance measures to improve operations. Through iteration and continual improvement of the self- and DOE-assessment processes, Livermore has markedly improved operations, as measured by factors such as cost efficiency, service timeliness, and work quality.

• Performance-based management as a means of building teamwork. In addition to team building within the Laboratory, Livermore's performance-based management system is fostering a closer working relationship among the Laboratory, UC, and DOE. Through a variety of forums, we are achieving better communication of performance expectations, more efficient oversight, and ultimately, improved performance.

4.1 Environment, Safety, and Health (ES&H)

Livermore's goals are that safety be integrated into programmatic and support activities as a top priority and executed in a cost-effective manner, that Laboratory operations be conducted in an environmentally responsible manner, and that ES&H performance be comparable to the best of our peers.

We expect to meet high standards of ES&H performance within our current operations budgets. To achieve our ES&H goals, our Laboratory culture must place high priority on ES&H as both a line-management responsibility and an individual responsibility, and ES&H must be fully integrated into all Laboratory activities, with appropriate balance between risk acceptance and costs.

Accidents are preventable through close attention to potential hazards and diligence by each individual and responsible organization. It is of paramount importance that employees take responsibility for making the Laboratory a safe place to work and that the community sees us as a good neighbor, concerned about safety as well as health and the environment.

Situation and Issues

Integrated Safety Management. The Laboratory policy is that safety of both workers and the public has the highest priority. Although we work with hazardous materials and perform complex operations, our activities must be conducted safely, with full protection given to workers, the public, and the environment.

We want to be recognized as an institution capable of carrying out challenging projects and state-of-the-art research and development in a safe manner. To this end, we have implemented DOE's ISMS in all aspects of Laboratory operations. The central themes of this cultural change are that each individual is responsible for his or her own safety, that work must be authorized before it can proceed, and that anyone can—and should—stop unsafe work practices.

Laboratory-wide ISMS embodies all of DOE's seven guiding principles and five core functions:

Guiding Principles

1. Line-management responsibility for safety.
2. Clear roles and responsibilities.
3. Competence commensurate with responsibilities.
4. Balanced priorities.
5. Identification of safety standards and requirements.
6. Hazard controls tailored to work being performed.
7. Operations authorization.

Core Functions
1. Define the scope of work.
2. Analyze the hazards.
3. Develop and implement hazard controls.
4. Perform work within controls.
5. Provide feedback and continuous improvement.

In addition, as part of Livermore's ISMS, the fundamental guiding safety principle states, "Each employee, supervisor, and manager is responsible for ensuring his or her own safety and promoting a safe, healthful, and environmentally sound workplace and community."

Environmental Management. Livermore's *Site Annual Environmental Report*, prepared each year by the Environmental Protection Department, summarizes the results of environmental monitoring and provides an assessment of the impact of Laboratory operations on the environment and the public. In addition to fulfilling our responsibilities to employees and neighboring communities, we must ensure that Laboratory programs comply with the National Environmental Policy Act (NEPA), the California Environmental Quality Act, and related federal and state requirements.

Direct funding for environmental restoration and waste management at the Laboratory is shown in Table 4-1. Environmental protection efforts include environmental monitoring, risk assessment, and analysis as well as major endeavors in environmental restoration—principally groundwater cleanup—and hazardous waste reduction and disposition. In the area of environmental remediation, considerable work has been done to clean up soil and groundwater contamination at the Laboratory's main site and Site 300 to meet community interests and satisfy regulatory requirements under Federal Facility Agreements. Both sites are on the Superfund list. At the main site, we have successfully removed much of the buried materials as well as reduced areas of contamination by using traditional and innovative soil-vapor and groundwater treatment systems. With these techniques, we have pulled back the contaminate plume to within the Laboratory's property line in the shallow groundwater zones. If adequate funding is provided, we are ready to operate existing facilities and complete the construction of the final treatment facility necessary to maintain control of all contaminate plumes by 2007.

Strategy Thrusts

Consistent Practices through ISMS. ISMS implementation is a steady-state effort at the Laboratory—not a one-time event. With ISMS in place, consistency and accountability in ES&H practices across the Laboratory will help us to meet safety goals while achieving cost efficiency. We will also work to strengthen the ISMS system by addressing opportunities for improvement and solidifying the ES&H enhancements that have been put into place as a result of implementing ISMS. Particular attention will be paid to three areas in which there are opportunities for improvement that were identified by the DOE Verification Team.

Through ISMS, we have established Laboratory ES&H policy guidelines and procedures that enhance accountability. Practices that are followed at high-performance, private-sector R&D organizations were studied as a guide. A major focus has been on better defining and articulating the flow of responsibility in Livermore's matrix management system. We have also reviewed our system of rewards and discipline for ES&H to assure consistency and to both promote safety and better deal with safety violations and poor safety performance.

As a part of ISMS, work activities are formally reviewed and authorized before work begins, consistent with the work planning and authorization process. In addition, the Laboratory's *ES&H Manual* has been updated and reorganized in a

Table 4-1. Direct funding for Environmental Restoration and Waste Management Program plans and initiatives, including capital funding (millions of dollars, $M).

	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY2006	FY 2007
Waste Minimization and Pollution Prevention	0.7	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Environmental Restoration	21.3	22.8	18.3	11.3	22.8	22.8	22.8	22.8
Waste Management	25.3	25.8	24.8	21.8	21.5	21.5	21.5	21.5

structure consistent with ISMS. Activities to implement ISMS have led to more consistent, clear communication of expected safety practices, effective training, and interchangeability of skills within the Laboratory. Clearly defined roles and responsibilities have been formalized through memoranda of agreement between organizations and facilities. These agreements, which are particularly important issues for the Laboratory's nuclear and other hazard-ranked facilities, delineate communication protocols, maintenance responsibilities, and reporting requirements.

Remediation and Restoration. We will continue activities to better characterize and clean up hazardous materials and contaminated groundwater at the Livermore site and Site 300. In these efforts, we will continue to develop and test innovative solutions that have broad application to environmental problems at other contaminated sites. We have made considerable progress in environmental remediation and restoration of the Laboratory, but much work remains.

However, future budget prospects are uncertain (see Table 4-1), and potential reductions may result in a funding level that is inadequate to meet the currently negotiated Federal Facility Agreements under the Comprehensive Environmental Response Compensation and Liability Act. With $18.3 million in FY 2002, we expect to continue operating the Livermore site to maintain hydraulic control of plumes from moving off-site and to reduce our effort to understand the movement of groundwater contamination at Site 300. The Laboratory continues to work with DOE to determine the appropriate scope of work that can be performed within the FY 2002 budget and to assist the Department with regulatory negotiations that will be needed to address compliance issues.

Cost Effectively Reducing and Managing Waste. Efforts are continuing to focus on the use and further development of cost-effective technologies and acceptable methods for pollution prevention as well as for waste reduction and management. We are taking concerted steps to reduce both the hazardous and nonhazardous waste generated by Laboratory programs. As for waste management, facilities and waste-handling operations are managed to minimize the impact on the environment and to maximize the efficient use of environmental management operating funds. We strive to continually improve efficiency and reduce waste inventory as we operate Livermore's waste facilities.

Despite successful efforts over the last five years to reduce waste management costs, increases in DOE and regulatory requirements coupled with yearly budget reductions put the Laboratory in a difficult position. An essentially level budget would allow the Laboratory to maintain only a minimally compliant waste-management operation, and any reduction below the FY 2001 budget ($23.3 million) will adversely affect waste-management operations.

An increase of $7.2 million above our FY 2001 budget for Waste Management is needed to make effective use of our new $62-million Decontamination and Waste Treatment Facility (with its improved safety systems) and to reduce transuranic (TRU) waste inventory at the Laboratory. An inability to move TRU waste to the Waste Isolation Pilot Plant (WIPP) in New Mexico increases both the costs and risk of our operations. Livermore currently has an opportunity to use the WIPP mobile vendors for certification of the TRU waste inventory in FY 2002, thereby allowing shipments of TRU waste to begin in 2002 and be completed in 2003. If this opportunity is missed, shipments could be delayed for a long time due to WIPP access issues, and we may have to curtail some operations that provide vital support to our national security programs.

4.2 Laboratory Security

Protection of sensitive information, nuclear materials, and other valuable assets at the Laboratory is a critically important aspect of responsible operations. Effective protection depends on the efforts of the Laboratory's safeguards and security professionals, computer security experts, program security officers, computer system administrators, and counterintelligence specialists as well as the proper training and vigilance of all employees.

We take security very seriously at Livermore and have greatly expanded our efforts since the events of September 11, 2001. An extensive apparatus is in place at our Laboratory, and we continually make adjustments and upgrades to address new threats and concerns. Protection is provided by employing increasingly sophisticated measures in a cost-efficient manner through a triad of security—physical, cyber, and counterintelligence.

Physical Security, based on a series of defensive layers and access control, is implemented by our Safeguards and Security Program. We take a graded approach to physical security in which physical barriers (e.g., fences, doors, repositories, and vaults) and permitted access are increasingly stringent, depending on the value or sensitivity of the asset.

Cybersecurity provides protection of the Laboratory's electronic information, computers, data networks, and telecommunications systems in a world that is growing ever more interconnected and dependent on the transfer of digital information. The mission of the Computer Security Program (CSP) is to ensure the protection of information and computing resources at a level commensurate with the assessed risk and the value and sensitivity of the resources, as determined by the Laboratory's line managers. CSP is involved in all aspects of Livermore cybersecurity, including security architecture development; the implementation, deployment, and operation of the security infrastructure; policy development and implementation oversight; and compliance validation. Our computer security experts incorporate Laboratory requirements, best business practices, and DOE orders relating to computer security to create a balanced computer security program. CSP also coordinates training on computer security issues and provides capabilities in threat analysis, incident response, and computer security forensics.

Counterintelligence at the Laboratory is the responsibility of the SAFE (Security Awareness for Employees) Program. SAFE was formed in January 1986 in response to a Presidential Decision Directive dated November 1, 1985, that required all U.S. government agencies to establish their own counterintelligence programs. SAFE's purpose is to identify and counter foreign intelligence threats against Laboratory personnel, information, and technologies.

Situation and Issues

Security Challenges of the 21st Century. A major challenge facing the Laboratory is to protect the staff and sensitive information and technologies as we participate in an increasingly global scientific and technical community. As a national security laboratory, Livermore is a work environment for over 8,000 people and a repository of sensitive and classified information, special nuclear materials, and other valuable government property. In the ongoing war against terrorism, the people and physical assets of the Laboratory are potential targets and must be protected accordingly. At the same time, access by non-Laboratory employees to many of Livermore's facilities is necessary. We work in partnership with universities, industry, and other laboratories on many unclassified projects. More generally, we are part of the international science and technology community and depend on interactions with others to be cognizant of major advances and to acquire special expertise needed to accomplish mission goals.

Heightened Awareness of Security Issues. Security depends on the vigilance of everyone—from senior managers to individual employees. Workers are trained to be aware of potential terrorist threats against the Laboratory as well as severe consequences of security violations that place nuclear secrets at risk. Staff awareness of security issues and foreign intelligence-gathering efforts at the NNSA laboratories is very much heightened as a consequence of the attacks on the U.S. and the highly publicized security incidents in 1999 and 2000.

We rely on a comprehensive Safeguards and Security Awareness Program at the Laboratory to understand the threats that we face and to be properly trained in responsibilities, proper procedures, and best practices. In addition to a series of DOE mandatory briefings—many of which are annual requirements—the Laboratory offers nearly a dozen additional programs, some of which train people for specialized security responsibilities. Each year, employees are required to complete security refresher training, and those that do not complete it or fail the follow-on test have their clearances suspended or revoked.

An Extensive Security Apparatus. An extensive security apparatus is in place at Livermore. In the area of physical security, our defense-in-depth approach includes a system of clearances, badging, and background checks; physical barriers and access control to protect sensitive and classified assets; and a fully trained and accredited security force. Since the terrorist attacks, Livermore's protective service officers have operated on a heightened state of alert, taking additional measures to make sure that the Laboratory is safe and secure. In addition, a vigorous Operations Security (OPSEC) Program serves to identify potential "open" pathways to sensitive information in Laboratory operations and recommends cost-effective countermeasures to deny exploitation.

A defense in depth also characterizes cybersecurity at the Laboratory. Our classified computer and unclassified computer networks are totally separate. All systems connected to the classified system are secure, and access to information on the classified system is on a need-to-know basis. For unclassified computers connected to the outside world, we provide protection against intrusion, monitor traffic, and respond to incidents. Moreover, DOE's Computer Incident Advisory Capability (CIAC) provides on-call technical assistance to DOE sites and other government agencies facing computer security incidents, such as break-ins, attempted break-ins, viruses, and scans by outsiders.

Livermore's counterintelligence program, SAFE, was established in 1986 and has grown in response to the Laboratory's increasing number of foreign interactions, particularly lab-to-lab programs. SAFE—largely staffed by former FBI special agents—works closely with the FBI and is well integrated into the U.S. counterintelligence community.

Our security performance is currently rated satisfactory (the highest rating) by DOE's Office of Independent Oversight and Performance Assurance. Similarly, the Laboratory received a satisfactory rating in all security areas from the DOE OAK/NNSA for the review period ending June 30, 2001. Nevertheless, security requires vigilance, and we continue to make upgrades to strengthen all aspects of security, address identified issues, and deal with perceived weaknesses.

Strategic Thrusts

Integrated Safeguards and Security Management (ISSM). In a memorandum dated March 26, 2001, NNSA administrator General John Gordon announced steps being taken to implement ISSM within the NNSA complex. At Livermore, the development of an ISSM system designed to meet our needs is a key part of our efforts to constantly strengthen security at the Laboratory. In developing ISSM, we will focus on enhancing security mechanisms already in place. One objective is to improve the ability of all aspects of security to be systematically integrated into management and work practices at all levels. Another is to streamline processes and procedures where possible. The implementation of ISSM will further our efforts to maintain a modern and effective security program at Livermore, and it will demonstrate to the nation our commitment to a strong security system at the Laboratory.

Livermore's ISSM system is being developed based on the framework for ISSM issued by NNSA. That framework provides a set of NNSA components for the Laboratory to use in creating its ISSM system. An overarching goal for ISSM is for all employees to be fully aware of and understand the Laboratory's security program and requirements. We plan to develop an ISSM system that:

- Provides employees clearly defined security roles, responsibilities, and expectations.
- Defines expectations for the work being done.
- Focuses on security awareness.
- Provides employees with better tools for meeting the security expectations placed on them.
- Assures that all employees understand what needs to be protected and why.
- Fosters in all employees an understanding of the need for continuous improvement and feedback in regards to security.

A two-year timetable was established for implementing an ISSM system at Livermore. The first step in the process included sending to all employees the booklet *An Introduction to Integrated Safeguards and Security Management for Laboratory Employees* (May 2001). It provides the principles, goals, and functions of ISSM as well as information about the process and timetable for developing the ISSM system. An early goal of ISSM development has been to engage the workforce in providing feedback on security procedures and practices. This has been done through a series of focus groups. The feedback is an important element in developing a gap analysis and subsequent plan for implementing improvements. The action plan will be developed by the end of September 2001. Implementation will then begin, and the Laboratory's ISSM system will be in place by December 31, 2002.

Effective Physical Security. The Laboratory regularly prepares a comprehensive Site Safeguards and Security Plan, predicated on the DOE Design Basis Threat, that details the computer, physical, and procedural measures we are taking. In general, the physical security of the Livermore site (and Site 300) is maintained through a multilevel, graded approach to limit access and protect information. The Laboratory is compliant with all DOE security requirements. In addition, in response to evolving security requirements, the Laboratory continues to make physical security improvements. All NNSA sites, including Livermore, have reevaluated the physical security of facilities to develop a prioritized list of upgrades in anticipation of increased NNSA funding to counter the threat of terrorism.

We also continue to pursue technological innovations, such as sophisticated detection systems and the automated portals developed at Livermore to minimize costs. Our automated portal system (Argus) has been adopted as a DOE standard and is being installed at other facilities.

Attention to Security Procedures for Foreign Interactions. Physical security measures are augmented by a system of security controls that apply to day-to-day operations. Specific issues that are raised by foreign nationals' visits and assignments to the Laboratory, as well as sensitive foreign travel by our staff, are addressed on a case-by-case basis. A foreign visit or assignment involving a sensitive country, a sensitive facility, or sensitive information undergoes careful individualized scrutiny, and it requires completed indices checks, a review for sensitive unclassified information, and an individual security plan. Other visits and assignments are conducted through a standard security plan.

Highest Standards of Computer Security. Revolutionary changes have occurred in information technologies—for example, portable hard drives can hold gigabytes of data, orders of magnitude more information than the Laboratory's mainframe computers in the 1970s. Concerns about the implications for espionage involving computer-based information and codes have spurred a thorough reassessment of computer security at the NNSA laboratories and a well-defined program to enhance cybersecurity. Additionally, we are using our computer security upgrade as an opportunity to apply our multidisciplinary approach to science and technology to become a model for computer security.

Significant improvements made to our computer security in the last two years include policy development, technical integration of intrusion detection and reaction capabilities, an information security architecture, a computer-systems vulnerability scanning and remediation program, a significantly improved institutional firewall capability, improved computer-security training, elimination of the possibility of transferring classified information with compatible media within an office, intrusion detection on classified systems, institutional computer virus protection, and implementation of a three-level network architecture. In a stand-alone evaluation of cybersecurity in February and March 2001, DOE's Office of Independent Oversight and Performance Assurance (OA-10) rated our classified and unclassified computer security programs as "satisfactory," and we again received a "satisfactory" overall rating for security from both OA-10 and DOE/OAK in their comprehensive FY 2001 security evaluations.

Cybersecurity improvements continue to be made. In conjunction with the University of California and Los Alamos, the Laboratory is working with Aegis Research Corporation, a recognized national security consultant. Aegis is reviewing our cyber defenses and providing workshops on cyber threats. We are finalizing standard-configuration guidelines for operating systems on all Laboratory networks, and we continue to deploy intrusion detection systems on all computer networks. In addition, we are refining the processes we use to assess cybersecurity risks. Key to progress in cybersecurity over the past two years is the strong support from senior management.

A Vigorous Counterintelligence Program. Our counterintelligence program (SAFE) develops threat assessments for the Laboratory, reviews visits and assignments by foreign nationals, and runs a vigorous Laboratory-wide counterespionage awareness program. SAFE was identified as a model for similar programs throughout DOE in a review of the program by DOE's head of counterintelligence in April 1998.

We continue to improve SAFE's capabilities so that the Laboratory's security measures stay ahead of increasingly challenging espionage threats. For example, we have installed the Visitor Tracking System for use at Livermore. Information on each foreign visit and assignment is entered into the system as part of the review and approval process. The database automatically captures numerous pieces of information about each visit and assignment and can provide statistics as needed. A similar system has been developed and is used for employees who go on official travel to foreign countries.

We also continue to upgrade our extensive employee espionage awareness programs. The SAFE staff provides briefings and debriefings for personnel who host foreign visitors or travel abroad and sponsors Laboratory-wide presentations on espionage-related topics by guest speakers from the U.S. intelligence community.

4.3 Laboratory Personnel

Livermore's principal asset is its quality workforce. The Laboratory seeks a highly talented, productive, motivated, flexible staff that is committed to Livermore's goals and reflective of the diversity of California and the nation. We strive for a work environment in which all employees can contribute to their fullest and feel valued for their role. The size, job classification, and diversity of Livermore's career-employee workforce are characterized in Tables 4-2 and 4-3.

We value the dedicated efforts of all our workforce in contributing to the scientific, technical, operational, and administrative success of the Laboratory. Breakthrough accomplishments are critical to the success of Livermore's programs and provide the foundation for future programs to meet national needs. These accomplishments are only possible in an environment with safe and efficient operations. In all our activities, we recognize and reward both individual and team excellence in performance. All employees are encouraged to take pride in and responsibility for their work, improve their skills, and continue their professional growth.

Situation and Issues

Strong Bond with the University of California. The recent extension of the contract between DOE and the University of California to manage the Laboratory is critically important to our continuing ability to recruit and retain an outstanding workforce. For the technical staff, the Laboratory provides challenging scientific programs, world-class research facilities and creative research opportunities plus the association with the University of California that has led to an array of scientific and technical ties to academia that would not have been possible otherwise. More generally, all employees have the opportunity to work in a collegial atmosphere with talented peers in solving difficult problems of national interest.

The strong bond between Livermore and the University nurtures an atmosphere at the Laboratory in which independent views and technical honesty are core values. University of California management of Livermore also provides employees an excellent benefits package and a policy framework for the Laboratory's human resources program.

Recruiting and Retaining High-Quality Employees. Despite these competitive advantages, there is significantly increased competition for the best people, and in many skill areas demand far outpaces supply, e.g., computer scientists and optical engineers. The Laboratory's recruitment strength

Table 4-2. Laboratory staff composition as of March 31, 2001 (excludes summer hires and temporary program participants; may include indefinite employees).

		Management	(%)	Scientific	(%)	Administrative	(%)	Technical	(%)	Others	(%)	Totals	(%)
White	M	813	(64.1)	1,343	(70.4)	135	(23.3)	965	(65.3)	414	(32.8)	3,670	(56.5)
	F	258	(20.3)	240	(12.6)	321	(55.4)	240	(16.2)	496	(39.2)	1,555	(23.9)
Black	M	29	(2.3)	22	(1.2)	10	(1.7)	39	(2.6)	44	(3.5)	144	(2.2)
	F	12	(0.9)	10	(0.5)	20	(3.5)	11	(0.7)	38	(3.0)	91	(1.4)
Hispanic	M	43	(3.4)	42	(2.2)	9	(1.6)	92	(6.2)	87	(6.9)	273	(4.2)
	F	30	(2.4)	13	(0.7)	26	(4.5)	14	(0.9)	91	(7.2)	174	(2.7)
Indian	M	15	(1.2)	7	(0.4)	4	(0.7)	19	(1.3)	16	(1.3)	61	(0.9)
	F	5	(0.4)	0	(0.0)	9	(1.6)	9	(0.6)	11	(0.9)	34	(0.5)
Asian	M	37	(2.9)	160	(8.4)	15	(2.6)	55	(3.7)	36	(2.8)	303	(4.7)
	F	24	(1.9)	52	(2.7)	30	(5.2)	21	(1.4)	26	(2.1)	153	(2.4)
Total minority	M	124	(9.8)	231	(12.2)	38	(6.6)	205	(13.9)	183	(14.5)	781	(12.0)
	F	7	(5.6)	75	(3.9)	85	(14.7)	55	(3.7)	166	(13.1)	452	(7.0)
Unidentified	M	2	(0.2)	18	(0.9)	0	(0.0)	10	(0.7)	3	(0.2)	33	(0.5)
	F	0	(0.0)	2	(0.1)	0	(0.0)	2	(0.1)	2	(0.2)	6	(0.1)
Totals	M	939	(74.1)	1,592	(83.4)	173	(29.9)	1,180	(79.9)	600	(47.5)	4,484	(69.0)
	F	329	(25.9)	317	(16.6)	406	(70.1)	297	(20.1)	664	(52.5)	2,013	(31.0)
Lab totals		1,268		1,909		579		1,477		1,264		6,497	

Table 4-3. Laboratory staff composition as of March 31, 2001 (excludes summer hires and temporary program participants; may include indefinite employees).

	None	AA	BA/BS	MA/MS	PhD	Total pop.
Management	300	113	229	254	372	1,268
Scientific professional	22	6	514	537	830	1,909
Administrative professional	228	41	199	95	16	579
Technical jobs	730	491	231	24	1	1,477
Other jobs	1,022	162	76	4	0	1,264
Totals	2,302	813	1,249	914	1,219	6,497

has been based on the work environment, the importance of the national security work, and exciting technical challenges. However, compensation is also important. The Laboratory's compensation system is structured to recognize superior performance and is driven by the "market." However, the Laboratory has not been able to match the total compensation offered by private industry, particularly in the highly competitive San Francisco Bay Area.

A Skilled and Flexible Workforce. The Laboratory's goal is an employee population having the motivation, innovation, and diversity needed to excel in its mission. It is also important to retain a degree of flexibility in staffing. Program redirections will continue to occur as national security, energy security, and environmental quality requirements change.

In addition, we have increased emphasis on leadership training. The Laboratory's future depends on the continual development of leaders who are visionary, skilled in managing and building programs, and sensitive to workforce needs.

Strategy Thrusts

Workforce Survey. Many factors over the last several years have affected the workplace at Livermore—increased competition for quality employees, increased external oversight, and new policies and procedures regarding safety and security. To better and more systematically understand the issues facing employees and assess their views, the Laboratory conducted a formal survey of employees' opinions in June 2001. The survey, Assessing the Workplace, was developed through close interactions between Laboratory staff and a leading survey firm. Questions focused on issues such as job satisfaction and work environment; growth opportunities, career development, and retention; diversity and equal opportunity; and overall management of the Laboratory.

The survey results are being used to measure broad Laboratory views, identify employees' priorities, and identify specific issues and potential solutions. By better understanding key workplace issues, Livermore will be positioned to more effectively respond to the needs of the increasingly diverse workforce of the 21st century. Survey action teams have been formed to make recommendations for improvements in seven focus areas identified through the survey:

- Salary and Compensation.
- Training and Career Development.
- Performance Management.
- Work/Life Balance.
- Employee Empowerment.
- Technicians and Facilities Support Workers.
- Postdoctoral Fellows.

The 10- to 12-person action teams are staffed by employees from across the Laboratory with support from Human Resources and other organizations where appropriate. Their work is slated to be completed by February 2002. An overall Survey Action Steering Committee is facilitating communications among the teams and monitoring overlap of efforts.

Science Day and Employee Focus Groups. In addition to the Assessing the Workplace survey, a series of three employee focus groups were held in March 2001, in conjunction with the NNSA Science Day celebration held at Livermore (Science Days were also held at Sandia and Los Alamos national laboratories, where similar focus groups met). The three groups were divided along demographic lines: early career (including postdoctoral fellows), mid-career, and senior scientists and engineers. A report of the focus groups, which included participation by several senior DOE/NNSA staff, was reported to General Gordon, NNSA administrator. The major issues were also reported to all Laboratory employees.

Recruitment and Retention. Like other employers, we are finding that recruitment and retention are major issues for the Laboratory. Our goal is to ensure that our ability to attract and retain employees remains competitive for the type of skills we need. To that end, we will use the results of the workforce survey to review policies and practices related to human resource functions and an overall collegial work environment.

The highly competitive labor market of the Bay Area continues to be a challenge to our recruitment and retention efforts, particularly in the "hot" skills. We monitor regional as well as national compensation practices and have taken steps in recent years to boost our competitiveness for these needed skills. Additionally, in February 2001, the Laboratory instituted an Employee Referral Bonus Program for positions that are designated as bonus-eligible; and Human Resources conducted workshops to train "employee recruiters" as well as set up a Web site showing how the program works.

Attention to Workforce Diversity. A focal point for our efforts to ensure equal employment opportunity and workforce diversity is the Laboratory's Affirmative Action and Diversity Program (AADP). In addition to monitoring compliance with relevant executive orders and legislation, AADP develops the Laboratory's action plans to increase diversity, sponsors a variety of outreach programs, and interacts with employee network groups to foster strong working relationships among these diverse associations. AADP provides funds to these groups to promote cultural awareness and support for scholarship funds.

To promote Livermore as an employer of choice, AADP staff members participate in conferences for recruitment and educational purposes, support collaborative partnerships, and cosponsor scholarships with external organizations. As an example, AADP cosponsored the Mexican American Engineering Society (MAES) national conference held in Santa Clara, California, which was attended by over 800 participants. The Laboratory also supports local and national service and community-action programs that improve employment opportunities for women and minorities. These outreach activities aim to help the Laboratory meet immediate and future hiring needs by reaching the broadest population, thus ensuring that all employment pools are diverse and represent the population available in specific career areas. For a summary of AADP's broad range of activities, see its Web page, www.llnl.gov/aadp/.

More generally, the annual workforce plans that are developed and implemented at the Laboratory consider both programmatic needs and institutional goals, such as achieving a workforce that is reflective of the rich diversity of California and the nation. It is essential that the Laboratory develops and maintains a diverse workforce and provides employees and applicants for employment with a discrimination-free workplace.

Actions against Racial Profiling. In the wake of an incident in 1999 that raised concerns about Chinese espionage at DOE laboratories, the potential for racial profiling against Asian Pacific Islander Americans at all DOE laboratories and facilities was recognized as a serious concern. DOE and the Laboratory made clear that racial profiling is unacceptable. We have acted on the recommendations of the DOE's Task Force against Racial Profiling (January 2000) to ensure that managers and employees neither commit nor tolerate racial profiling and to prevent discriminatory actions against all employees. The issue continues to receive management attention, including steps to develop an enhanced framework for resolving workforce diversity issues. A Diversity Issues Workshop in August 2001 for NNSA administrators and laboratory directors focused on Asian Pacific American workers' issues. A diverse workforce is essential to the future health of the Laboratory, and Asian Pacific Islander Americans, very much part of both the northern California area and the scientific community, must feel as welcome and appreciated at the Laboratory as all employees and visitors.

Employee Development. The Laboratory's workforce plans set recruiting requirements for various skill areas and provide areas of emphasis for employee development. The Laboratory supports training, education, and career-development programs for individuals that meet their needs for growth and are consistent with short- and long-term Laboratory goals. The goal is to ensure that employees have the best skills, training, and tools to accomplish their current work and to prepare for future assignments. Most classroom training activities are conducted at the Laboratory's 8,000-square-foot Laboratory Training Center, designed with facilities, equipment, and staffing to enhance learning and information exchange. Three standard classrooms and one computer classroom support online media input and video broadcasts from the Laboratory TV network.

Leadership and Management Development. A particular area of emphasis for the Laboratory is training for supervisors and managers. We have a set of core courses for supervisors and managers: Supervision I for new supervisors, Supervision II for all supervisors, and the Management Institute for division leaders and above. These programs are designed to assure that all supervisors and managers understand their full responsibilities, including Laboratory policies and procedures, and develop solid leadership and people skills. Senior managers are actively involved in the design and implementation of these programs and serve as the faculty for Supervision I and the Management Institute.

The Laboratory piloted a Management Institute in spring 2000. Designed to help prepare the next generation of Laboratory leaders, the institute received highly positive responses from participants, who especially valued interaction with top managers during the two-day-long program. This successful management-training program continues to be run on a biannual basis, with each session targeted at a new group of potential future Laboratory leaders.

In addition, in FY 2001, Livermore instituted the Project Management Professional Certification Program developed and run by Project Management Institute (PMI). The institute is the leading nonprofit association of project management professionals. Its eight-week class is run on-site for Livermore and DOE-OAK employees, and participants who pass a four-hour exam gain PM certification. The Laboratory also sponsors a Leadership Lecture Series featuring keynote speakers on leadership topics. Open to all employees, the lecture series reflects our commitment to building leaders at all levels of the organization.

4.4 Facilities and Plant Infrastructure

Lawrence Livermore National Laboratory comprises two sites: the main Livermore site and Site 300, a 28-square-kilometer remote explosives test facility located about 25 kilometers southeast of Livermore. The Livermore site has 181 permanent buildings and 245 temporary structures and houses over 9,000 people. At Site 300, there are 101 permanent buildings and 38 temporary structures. The replacement plant value is estimated to be $3.2 billion, which does not include some $2.0 billion in personal property and land value (see Tables 4-4 and 4-5). Personal property—attractive items and/or property with purchase prices over $25,000 ($900 million of the total)—are subject to inventory.

In a generally stable future projected for the Laboratory population, the facility square-footage inventory given in these tables is considered adequate to meet future needs. However, replacement and rehabilitation of substandard and technically obsolete space, as well as modernization of technical capabilities, shall be continuing requirements in maintaining the inventory.

Stewardship of DOE lands and facilities at Livermore is an important responsibility. We have world-class scientific facilities that are essential for national security and provide unique capabilities to meet other enduring national research and development needs. Facilities and infrastructure—and our investment strategy for maintenance, renovation, and new construction—must be aligned with the Laboratory's programmatic and operational requirements.

We want every employee to take pride in Livermore's campus setting—a physical plant that is attractive, accessible, and designed to be cost effective and inviting. This goal requires modern facilities at the Laboratory, designed and sized for current and future operations and well maintained at competitive costs. A quality campus environment attracts top-notch employees, enhances workforce productivity, and helps ensure programmatic success.

The challenges we face stem from our expectation of minimal new office construction in the near term and the need for sufficient resources to achieve our goal through site revitalization. As described in the Laboratory's *Comprehensive Site Plan*, our strategy includes a balanced set of efforts to rehabilitate older facilities, consolidate activities as mission priorities change, maintain mission-critical aging facilities, and efficiently manage legacy facilities.

Situation and Issues

Upgrades and New Construction. Unique, state-of-the-art, experimental research facilities are a core strength of the Laboratory. The major national security directorates all have some modern core facilities in use or under construction. Construction is in progress on the National Ignition Facility, which will be a cornerstone of the nation's nuclear weapons Stockpile Stewardship Program. In addition, construction is planned to begin in FY 2002 for the Terascale Simulation Facility to house the Laboratory's ASCI computers and needed office space for the program.

The modern office space designed into these research facilities—and the space in other recently constructed facilities at the Laboratory—helps to improve the overall living conditions of the Laboratory population. Recent investments such as electrical and infrastructure modernization have also helped to upgrade the Livermore site. In addition, the communication and information systems infrastructure at the Laboratory has undergone continual upgrade, in part to keep pace with the unprecedented high-performance computing capability that Livermore is acquiring.

Rehabilitation and Replacement. Strategic management of Laboratory facilities must balance the needs and resources for maintenance, facility rehabilitation, and new facilities development. Many structures are 30 to

Table 4-4. Laboratory space distribution.

Type of space	Area in 1000s of Square feet	Square meters
Main site	5,905	548.6
Leased-university	0	0
Leased-off-site	82	7.6
Site 300	369	34.3
Total	6,356	590.5

Table 4-5. Facilities replacement value (in $M).

	Buildings	Trailers	Other structures	Utility/infrastructure	Total
Livermore Site	1,899	86	4	995	2,984
Site 300	127	1	14	109	251
Total	2,026	87	18	1,104	3,235

50 years old (see Figure 4-1). They are particularly demanding for maintenance to keep them adequate, and over time, all will need rehabilitation or replacement. Only 66% of our employees currently reside in permanent space, and the majority of temporary office space (65%) is nearing or already beyond the end of service life. As more facilities age substantially beyond their intended life, our need for modern office space will continue to grow. Figure 4-2 shows the current condition of Laboratory space.

The health and safety of employees are of primary importance to the Laboratory. Any facility that poses a risk in this regard is vacated, rehabilitated, or removed, and the occupants are relocated. In addition, from long-discontinued programs, we have outdated and unusable laboratory space that must be decommissioned, decontaminated (where necessary), and/or demolished. Livermore's legacy facilities and other excess marginal space requires considerable investment to rectify (e.g., clean up, rehabilitate, reconfigure for a different use [adaptive reuse], or remove).

To efficiently manage our older facilities, site planners employ a scoring system of 0–4 for 12 criteria to identify facility candidates for rehabilitation or removal. The system, referred to as the Facility Assessment and Ranking System (FAaRS), helps us to prioritize institutional maintenance requirements and to keep our mission-essential aging facilities operational and in adequate condition. Prompted by FAaRS, the Laboratory has made significant reductions in substandard space in recent years, by removal, rehabilitation, or mothballing (see Table 4-6).

The NNSA/DP Infrastructure Recapitalization Initiative. Many mission-supporting facilities at Livermore and other NNSA sites are nearly 50 years old or older. Some need replacement immediately. The others are particularly demanding for maintenance to keep adequate, and over time, all need rehabilitation or replacement. The aging of the NNSA weapons complex was a focus of concern of the Panel to Assess the Reliability, Safety, and Security of the United States Nuclear Stockpile (the Foster Panel). One of the panel's major recommendations was to "restore missing production capabilities and refurbish the complex," and it cited a DOE estimate of maintenance backlog at $700–800 million.

Motivated by this need, NNSA/DP launched a concerted effort to improve facilities and infrastructure management by instituting better processes for strategic planning, budgeting, and execution. The goal has been to develop an NNSA/DP Facilities and Infrastructure Management Plan through a corporate approach to the problem and to institutionalize the processes that were implemented. We are fully supportive of NNSA's effort, and our Laboratory and other sites in the complex are contributing to it. New monies are needed to prevent further deterioration of the complex and, over time, restore it to better health.

Strategy

A Balanced Portfolio for Site Revitalization. Our objective is to follow a balanced approach in providing facility management to meet programmatic needs, with the goal of assuring the future vitality of the Laboratory and its primary missions. In particular, a coherent Laboratory-wide office requirements plan is continually refined to address the needs of the nearly 4,000 employees who work in trailers, modular units, and World War II–era buildings that we keep operational by using the FAaRS and maintenance backlog ranking processes to prioritize

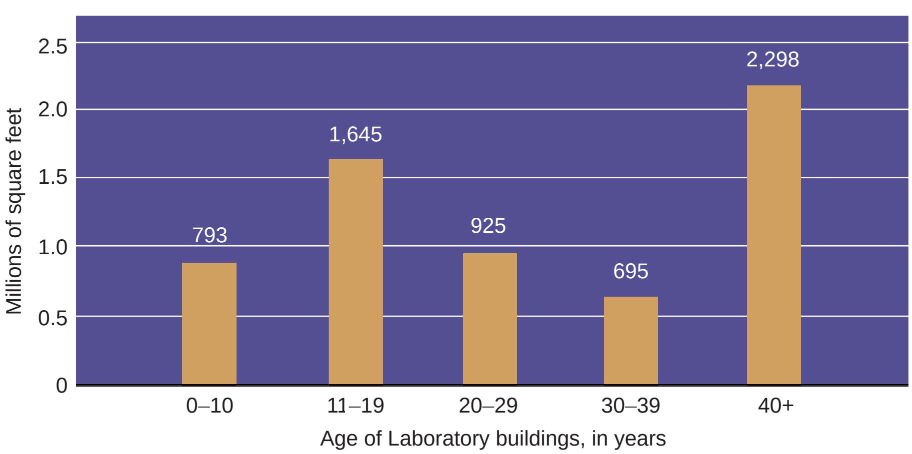


Figure 4-1. Age of Laboratory buildings.

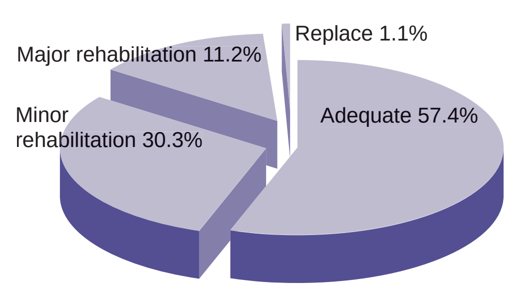


Figure 4-2. Condition of Laboratory space.

facility investments. Four principal elements of the plan are:

- Construction of new facilities through line items and general plant projects.
- Rehabilitation of older facilities, where cost effective.
- Prioritization and reduction of deferred maintenance backlog.
- Efficient management of legacy facilities.

Our ability to carry out a balanced portfolio of plans for site revitalization depends on the availability of adequate funding to do so. With Readiness in Technical Base and Facilities (RTBF) as one of the three organizing thrusts of the Stockpile Stewardship Program (see Section 2.1.4), it is clear that the Laboratory's principal sponsor, NNSA/DP, recognizes the importance of modernizing its national laboratories. On the other hand, NNSA/DP is under considerable stress with many competing demands for investments—stockpile life-extension programs, stewardship campaigns, new research facilities, and revitalization of both laboratories and production facilities. Funding projections show lower-than-historic levels of funding for infrastructure line items and General Plant Projects, and there are many competing demands within the Laboratory for internal investments.

We continue to improve our processes for managing site revitalization. Technology has changed requirements for the types and amounts of space in which we work; and so, in consultation with DOE/OA, we have changed some definitions and requirements for planning and managing our sites. The changes help to address the space issues we face today—distribution and rehabilitation of existing space where feasible for new purposes and equipment rather than new construction. With our new priority rating system, we will more quickly fix current problems and be able to plan for the kinds of facilities that the Laboratory needs for future programs.

New Technical Facilities. New technical facilities at Livermore are being constructed through DOE program investments. Two major new technical facilities—the National Ignition Facility and the Terascale Simulation Facility mentioned in Section 2 and on page 96—are the Laboratory's highest priorities. Scheduling the many nontechnical facility line-item construction projects is a product of (1) the priorities that the Laboratory has set on each project, and (2) discussions among the three NNSA laboratories and NNSA/DP to make the most effective use of overall funding.

Rehabilitating Older Facilities. To meet the greater portion of Laboratory office-space needs, we are rehabilitating our older facilities identified through the FAaRS to provide adequate quality office space where cost effective (Figures 4-3 and 4-4). Depending on the return on investment, older but fundamentally sound facilities are being returned to "good" condition by maintenance rehabilitation projects. In this connection, we are pursuing workable options for innovative, cost-effective, facility revitalization and new construction/renovation.

For example, through a pilot project, the Laboratory brought one of the World War II–era building complexes (B314/315), which has over 100 offices, up to good condition (an additional 15 years of life) at a very affordable cost. Space in a large open-bay building (T-1879) was rehabilitated and modified into four large, well-designed and well-equipped classrooms that meet the specific needs of the Laboratory's teaching and training organizations. Additional projects include the rehabilitation of trailers in the 1400 block to affordably revitalize an additional 200 office spaces from poor to good/adequate condition.

Reducing the Maintenance Backlog. A Laboratory Facility Charge (LFC) based on square footage is levied on building "owners" to support the costs of routine maintenance for their facilities and of Laboratory infrastructure. We are using and continuing to refine a planning process for work prioritization to reduce the Laboratory's maintenance backlog using G&A funds. Priorities are set by the programs, considering both the level of risk to the Laboratory's mission if there is a failure and the probability of failure (in the absence of replacement). The process assures that the prioritized backlog is addressed with planned expenditures using LFC funds.

Projects that rank highest in both criteria are "A list" items that require immediate attention. Other maintenance projects fall into less critical categories: "B" items to address within one year and "C" items to address in less than three

Table 4-6. Reduction in substandard space (in 1000s of square feet).

Fiscal year	Substandard space removed	Substandard space mothballed
1996	116.8	141.2
1997	28.1	23.6
1998	22.0	0.0
1999	24.9	137.7
2000	7.3	53.4
2001	27.8	65.4

years. These three categories constitute the Laboratory's Essential Backlog, representing approximately 20 percent of the total backlog. Immediate attention to long-range, lower-priority categories ("D" through "F") would bring all facilities up to as-built condition but would result in prohibitive expenditures. Items in these less-essential categories are addressed only when they move into the essential regime. Through this process, we have developed and are executing a multiyear institution-wide maintenance backlog reduction plan. Funding sources were allocated in FY 2000 through FY 2001 to correct all the "A" and "B" and the most important "C" deficiencies.

Infrastructure Recapitalization at Livermore. The Laboratory has provided input into the NNSA/DP Infrastructure Recapitalization Initiative. As mentioned, the initiative is intended to provide much-needed funds for facility maintenance and restoration, general plant projects, capital equipment, and decontamination and demolition of legacy facilities.

Projects at the Laboratory that are part of the initiative total $65.8 million for FY 2002, including $42.2 million for high-priority items. Some of the 12 high-priority projects are maintenance projects; general plant projects; capital equipment items including replacement of electrical power systems in aging facilities, building renovation projects, investments in high-efficiency particulate air (HEPA) filters to more effectively ensure that we continue to meet high environmental standards, a decontamination and demolition project, and a scoping and design study for rehabilitation of a major building complex on-site.

Facility Plans and Resource Requirements

Table 4-7 provides a summary of the Laboratory's funded and proposed construction projects with total estimated cost (TEC) in excess of $5 million. Construction projects that have recently begun or are proposed to begin in FY 2002 include:

Engineering Technology Complex Upgrade (ETCU) (FY 2002 start, TEC: $26.7 M). The ETCU project will revitalize and enhance capabilities of both facilities and equipment and consolidate activities in existing research, prototype fabrication, and metrology in the Building 321 complex. The ETCU project is critically needed for the Laboratory to support the Stockpile Stewardship Program. We must develop state-of-the-art capabilities for fabricating, measuring, inspecting, and testing critical weapon components. The National Ignition Facility will also benefit from the ETCU's new micromachining capabilities. When completed, the ETCU will consolidate manufacturing functions into one contiguous complex, which will improve operation efficiency and production quality, enhance scientific research, and reduce operating costs.

Sensitive Compartmented Information Facility (SCIF) (FY 2001 start, TEC: $24.6 M). The new SCIF is proposed as a two-story 5,400-square-meter building (or 58,000 square feet) to be sited on the west side of the Laboratory, adjacent and north of Building 132. The new SCIF is essential for the Nonproliferation, Arms Control, and International Security (NAI) Directorate to continue to carry out its

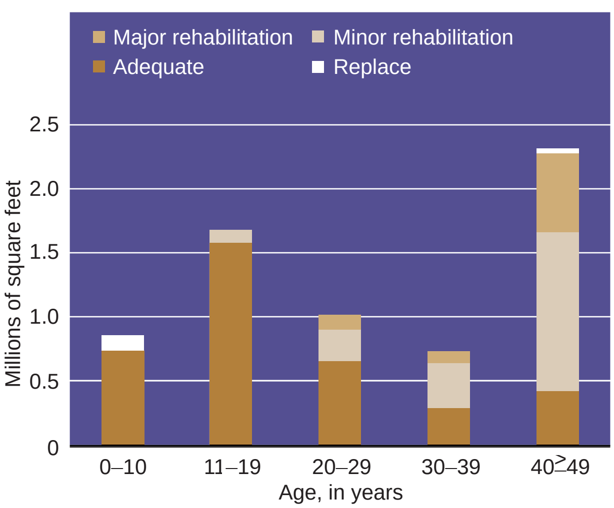


Figure 4-3. Use and condition of Laboratory space.

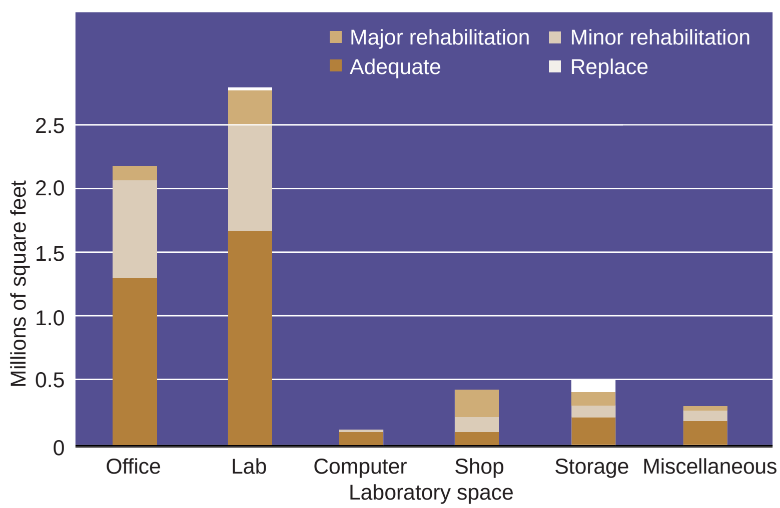


Figure 4-4. Age and condition of Laboratory buildings.

mission by providing major enhancements in information management, optical-fiber networking, storage and retrieval, and real-time communications with DOE and the intelligence community.

Terascale Simulation Facility (TSF) (FY 2000 start, TEC: $89.0 M). The project provides for the design, engineering, and construction of the TSF (Building 453), which will be capable of housing future computers required to meet the Accelerated Strategic Computing Initiative (ASCI). The building will contain a multistory office tower with an adjacent computer center. From its inception, the TSF has been designed to enable the very large-scale weapons simulations essential to ensuring the safety and reliability of America's nuclear stockpile. The timeline for construction is driven by requirements coming from ASCI within the Stockpile Stewardship Program. The TSF will house the computers, the networks, and the data and visualization capabilities necessary to store and understand the data generated by the most powerful computing systems in the world.

4.5 Business and Financial Support

Programmatic work at the Laboratory is supported by business, procurement,

Table 4-7. Funded and proposed major construction (in $M).[a]

Project title	TEC	FY 2000 BO	FY 2001 BO	FY 2002 BA	FY 2003 BA	FY 2004 BA	FY 2005 BA	FY 2006 BA	FY 2007 BA
Funded projects:									
National Ignition Facility	2,094.9	248.2	251.5	245.0	214.0	150.0	130.0	130.0	120.0
Terascale Simulation Facility	88.9	0.2	4.6	32.0	25.0	23.0	2.0		
Protection of Real Property - II	19.9	2.1	3.5	2.8	9.4				
Isotope Sciences Facility	17.4	1.2	2.0	4.4	4.0				
DARHT (support)[b]	19.4	5.5	4.8	9.9	13.3	13.8	14.4	15.0	
Decontamination/Waste Treatment Facility[c]	62.3	5.3	4.3	0.8					
Sensitive Compartmented Information Facility (SCIF)	24.6	0.0	1.5	13.0	9.6				
Electric Power System Upgrade[d]	26.8	0.4							
In-House Energy Management	18.4	0.0	0.2						
Site 300 Contained Firing Facility	49.7	17.4	7.7						
Site 300 Facilities Revitalization[d]	29.0	0.3							
Site 300 Fire Station/Medical Facility	5.4	3.3	0.1						
Total funded construction		283.9	280.2	307.9	275.3	186.8	146.4	145.0	120.0
Proposed Projects:[c]									
Engineering Technology Complex Upgrade	26.7			7.0	13.0	6.7			
Hydrogen Isotope Research Capability[c]	25.0				1.5	1.5	11.0	8.0	3.0
Energetic Materials Processing Center[c]	44.0				2.9	1.5	21.0	15.0	3.6
Microbiology Research Facility (non-DP)[c]	68.0				6.0	0.0	6.0	0.0	10.0
B435 rehab and modernization (non-DP)[c]	10.0				2.0	0.0	4.5	3.5	
Seismic upgrades[c]	25.0					2.5	0.0	10.0	8.5
Site Utilities Upgrade Project[c]	29.8						3.0	0.0	8.3
Building utilities[c]	28.8								2.9
Total new funding requirements				7.0	25.4	12.2	45.5	36.5	36.3
Total Laboratory		283.9	280.2	314.9	300.7	199.0	191.9	181.5	146.3

[a]Budget obligation (BO), FY 2000–2001; budget authorization (BA) FY 2002–2007.
[b]Support to a non-LLNL-managed line-item; TEC equals sum of expected funding.
[c]*Defense Programs Ten-Year Comprehensive Site Plan* (September 21, 2001) used to update information compared to Resource Tables in Section 5. Rehab of Maintenance Facilities project deleted; Hydrogen Isotope Research Capability, Microbiology Research Facility added, minor funding changes elsewhere.
[d]Project closed.

financial, and other types of services. Livermore is making considerable improvements in its operational support for programs, striving to size and manage support activities to optimize overall cost effectiveness and performance. As gauged by performance measures in the UC–DOE contract, Laboratory support functions are increasing in quality, delivered in a timely manner, and priced competitively.

We strive to provide operational services in a professional manner and to institute equitable procedures and systems that support Laboratory values. As a public-sector organization engaged primarily in contract work for DOE and other federal agencies, the Laboratory conforms to regulatory requirements—an important factor affecting the operations environment. Our support and service organizations provide assurance that compliance is managed responsibly and efficiently and in a way that is clearly defensible to the public, regulators, and Laboratory programs.

Situation and Issues

Reducing Support Costs. Many improvements have been made to reduce support and overhead costs, making more resources available for direct program work. The actions were taken with a view toward maintaining and improving institutional health and protecting the Laboratory's capability to conduct essential operations, such as in ES&H.

Functional elements that are responsible for providing many Laboratory-wide support services have undergone significant reengineering to improve efficiency, reduce costs, and better understand and meet customer needs and expectations. We have adopted best commercial practices whenever possible and optimized business information systems to improve communications at all levels. This reengineering has benefited from major changes at DOE—an outcome-based oversight model for some aspects of operations, a shift to an aggressive self-assessment process, and implementation of meaningful metrics to assess performance. Rapid changes in technology also offer many opportunities for improvements in information systems (see Section 4.6 Information Management for Business Systems).

Procurement and Materiel Requirements. It is the policy of DOE to fully integrate small businesses, small disadvantaged businesses, women-owned businesses, and Historically Underutilized Business Zone (HUBZone) business concerns in DOE's core mission and programs. Accordingly, the Laboratory is required to provide opportunities to increase to the maximum extent practicable the participation of these firms in our acquisition process. (See Table 5-2 in Section 5.)

In support of this requirement and on behalf of the Laboratory, the Procurement and Materiel (P&M) Department negotiates annual goals in prescribed socioeconomic categories. Using a sophisticated forecasting model and working in concert with resource analysts from around the Laboratory, P&M develops annual socioeconomic goals that are both reasonable and attainable. The goals, carefully monitored and compared to actual procurements throughout the fiscal year, may be adjusted at mid-year, depending on changes to individual program spending plans or the Laboratory budget at large.

Strategy Thrusts

The Laboratory will continuously improve systems and processes for providing support services, and we will also effectively communicate with and involve both employees and customers in the change process.

Anticipating Customer Needs. Successful reengineering includes anticipating customer expectations; soliciting continual customer feedback to assess satisfaction, needs, and strategies; and continuing aggressive use of industry and government benchmarking to enable effective comparisons and adopt best practices. Reengineering approaches will continue to take advantage of modern information technology and adopt off-the-shelf approaches whenever possible. (See also Section 4.6 Information Management for Business Systems.) In some cases, we will rely on institutional reinvestment to absorb short-term expenses that will lead to long-term cost savings. When outsourcing is a viable option, organizations are staffed to take advantage of it.

Balancing Priorities. In planning for and delivering operational support, the Laboratory strives to balance resource allocations so that programmatic work is performed responsibly, cost effectively, and in compliance with regulatory and other requirements. Implementation of this strategy also ensures that Laboratory policies permit local flexibility but not to the point at which local optimization undercuts compliance or other institutional objectives.

4.6 Information Management for Business Systems

The Laboratory's business systems and information planning process explores, compares, and learns about new business approaches and technologies that can be used to improve our business practices and information architecture. Our studies address crosscutting business issues in designing our future business systems architecture.

The themes for these planning processes include:

- Determining the crucial needs and directions for future Laboratory business systems.
- Identifying cross-organizational requirements for supporting external business partners.
- Determining best future practices that will achieve cost reductions, cycle-time reductions, quality improvements, and end-user self-service applications.
- Ensuring that explicit business systems align with Laboratory programs and projects.
- Understanding and influencing the strategic directions as determined by Livermore's information architecture activities sponsored by the Chief Information Officer (CIO).
- Identifying and recommending for implementation the best-of-class strategies, business systems, applications, and technologies from industry and sister laboratories.

Situation and Issues

Business Systems Architecture. The business system architecture must respond to changing business needs that require the use of evolving technologies. Managing and deploying an evolving business system and technical infrastructure have unique problems. In this type of environment, the complexity increases as the number of interrelated applications and users increases and as the time to technical maturity decreases. Our challenge is to provide an agile, responsive infrastructure with reliable, secure, and scalable production services. Meeting this challenge requires fusion between the Livermore business and technology strategies, continual prudent evolution of technical capability, and a future infrastructure designed for serviceability to our business units.

Our business systems architecture is heavily influenced and validated by benchmarking and best-practice activities. In our benchmarking process, we study large, technically sophisticated organizations that are familiar with technologies that are part of our current infrastructure and future directions. The organization can be a key technology vendor or other DOE national laboratory. During this process, we review information technology (IT) infrastructure, drivers of change, and future directions.

In the best-practices arena, the scope of the interactions is much more specific. First, we identify critical technology directions in which the solutions are unproven and relatively high-risk. We then find organizations that have experience and knowledge in the technical area and compare approaches and results. We also review our critical current technologies and processes to assess how we are doing.

In both cases, the objectives include:

- Identifying innovative approaches and technologies relevant to our future.
- Validating our major tactical and strategic directions, including feasibility, risks, costs, and benefits.
- Evaluating our strategic and tactical alignment with our vendors and the IT industry.
- Assessing our progress relative to similar organizations and industry as a whole.

During FY 2002 and beyond, we will investigate industry directions and implement major architectural changes, particularly in authentication, access control, intranet portals, workflow, integrated help-desk knowledge base, desktop and mobile computing management, and computer security.

Strategy Thrusts

Information Technology Professionals Recruitment and Retention. We continue to face strong competition in the demand versus supply of IT skills critical to the Laboratory, a situation that we believe will continue through 2006. The shortage of critically skilled IT professionals, particularly given our proximity to Silicon Valley, has made it imperative to create a strategic thrust in building and maintaining tomorrow's workforce. To shape our future directions, we are conducting a major initiative to study the possibilities and implications of new management styles required for the next wave of new employees, sophisticated reward systems, alternative workforce sourcing arrangements, and various recruitment models, practices, and policies for selective retention. These multifaceted studies will help us redefine and deploy robust, rational, and strategic IT skills-management programs.

Enterprise-Scale Applications. The fundamental driver for our strategic planning is enabling cost and cycle-time reductions or quality improvements for key business processes. For example, a number of leading-edge organizations have realized significant cost and cycle-time reductions by moving processes out to end-point participants via the Web and automating everything in between. These applications are sometimes referred to as enterprise self-service applications, which we have adopted as our primary strategic direction.

We are replacing manual processes with enterprise-scale self-service applications (timecard, training, budgeting, purchasing) delivered to the browsers at the desktop. The Web technologies also enable us to extend business processes to external vendors and partners. Over the last three years, our user population has gone from about 1,500 users to approximately 7,000 with little increase in infrastructure staffing.

Intranet Portals and Web-Based Systems. Providing customized Web portals for specific customer segments is a major trend in industry. Many organizations have internal home pages that provide access to Web sites, Web-based applications, and a common entry point for accessing the ever-increasing volume of Web content. In the first phase of a similar effort, we are implementing ways to provide a user-customizable intranet Web portal that integrates internal and external Web-site access, Web-based application access, workflow in-basket, messaging, and utilities integrated with single sign-on and integrated access control.

A second phase for this effort will be creating portals for specific customer segments, including workbenches for resource managers, enterprise users, project managers, and human resource managers.

Electronic Commerce Initiatives. The Internet is driving an emerging revolutionary business paradigm at Livermore. Virtual relationships and collaborations between Laboratory business units and external partners are emerging at an ever-increasing rate. We currently provide electronic data interchange based on just-in-time purchasing capabilities with a virtual catalog of over 1.5 million items. In the near term, we are expanding our use of collaborative technologies that support engineering designs and job orders, and we are moving forward with the application of commercial business-to-business purchasing networks.

4.7 Internal and External Communications

The Laboratory is a national resource center of applied science and technology. In this role, we serve diverse customers and strive to meet the needs of many stakeholders. These interactions range from the broad scientific community and the leaders of the federal government to our own local community and Livermore employees.

Through efforts of senior management, the Public Affairs Office (PAO), and others, Livermore continues to develop its internal and external communications program by bringing the Laboratory's messages to important audiences and seeking the concerns and comments of those audiences. Internally, the Laboratory needs effective communication to support dialogue on key issues, institutional decision making, and dissemination of institutional information. Externally, the Laboratory is striving to be seen locally, nationally, and internationally as a credible and authoritative source on issues relevant to our mission. We want to be perceived as an intellectual asset to the state of California and a helpful neighbor in the Bay Area and California's Central Valley, and we want the communities around us to be proud we are here.

Situation and Issues

Listening to Our Customers. The Laboratory must continue to ensure that customers and stakeholders are identified and that their concerns are considered in planning and decision-making as well as in the formulation of operational policies. The range of customers and stakeholders is extremely wide, from the general public to senior managers in Washington.

With the regional public in mind, PAO contracts for community and employee surveys to understand broad trends and specific issues and concerns. The latest survey, conducted in 2000 and the fourth within a decade, evaluated the public's needs and the Laboratory's performance; its purpose is to guide communications practices inside and outside the Laboratory. In 2001, a major survey of workforce issues is being conducted (see Section 4.3 Laboratory Personnel).

Broadly sought input will be used in 2002 to prepare a new strategic plan for the Laboratory. As the follow-on to *Creating the Laboratory's Future*, the strategic plan will put forth Livermore's vision, goals, priorities, values, and strategy and be widely distributed to both external and internal audiences.

Improving Community Relations. The Laboratory continues to reach out to stakeholders and customers, to participate in community events and to seek feedback directly as well as by formal survey (see preceding paragraph). From past surveys, we are aware that relations with the community are fundamentally sound, but most members of the community would like more information about our activities. PAO strengthened its community relations staff in 1999–2000, began a monthly electronic community newsletter, and began a public lecture series. It has been conducting regular tours for the community as well as special tours for select groups, such as a community leader tour of the National Ignition Facility (NIF) under construction. PAO is now focusing more on professional relationships with the news media than on producing written news releases. Community comment is solicited in all of these activities. PAO also arranges meetings between senior Laboratory management and community leaders, and the Laboratory participates in various public forums on environmental topics, NIF, and security issues.

Strategic Thrusts

Information Outlets. The Laboratory is using advances in technology to improve internal communications and external communication with the general public, local and regional audiences, and leaders in the federal government. We are using the Internet extensively for all of these audiences. For example, the Laboratory newspaper, *Newsline*, has an online version (*NewsOnLine*) that is issued twice weekly. Selected *Newsline* articles are posted on the publicly accessible PAO Web page. Similarly, Public Affairs news releases and photos are posted on the Web. *Newsline* and *Grapevine* (our internal Web page) carry a "From the Director" column, which provides employees with information about key institutional efforts and Laboratory issues. In 2000, with Sandia/Livermore and local cable TV, PAO began a biweekly talk show, "Technology Today," which reaches the local public with nontechnical discussions of projects at both Livermore laboratories.

Online Communications. Institutional publications, such as *Creating the Laboratory's Future, Science & Technology Review, Laboratory Annual Report*, *Institutional Plan*, news releases, and major stories from *Newsline* are available on the Laboratory's external Internet home page. More generally, Livermore's external home page is a national resource of science and technology information. Many publications are available online, and information is provided about our organization, operations, and programs as well as opportunities for employment and research partnerships.

Web pages for general public use, such as PAO's, recently have been redesigned for greater clarity and improved public access and usefulness. The Laboratory's internal Web page, *Grapevine*, is being completely revamped this year into an "enterprise portal" format, which will allow individual users to customize its functions. The *Grapevine* provides employees with organizational information, policies and procedures, institutional databases, online training and testing, standard forms, business information, event calendars, and electronic newsletters. Many administrative and operations Web sites have been cited as "best practices" by DOE.

The institutional lead for the Web is the deputy associate director for Computation, whose organization oversees standards and procedures for Web-page development. All Laboratory Web pages are administered by the Technical Information Department, and all pages, whether internal or external, must undergo review and release prior to official posting.

Involvement in the Community. In the local community, the director and other senior managers have increased their visibility through more frequent meetings with local officials and civic groups. For various local chambers of commerce, service clubs, and science fairs, Livermore managers and employees serve as board members representing the Laboratory or as volunteers. They also participate in ongoing activities of Tri-Valley (Livermore, Dublin, Pleasanton, San Ramon) business councils and economic development leadership committees, serve as the spearhead for memoranda of understanding between the Laboratory and nearby community colleges in the field of workforce development, and participate in a youth summit, Livermore's Promise: Alliance for Youth, which is an offshoot of General Colin Powell's national effort.

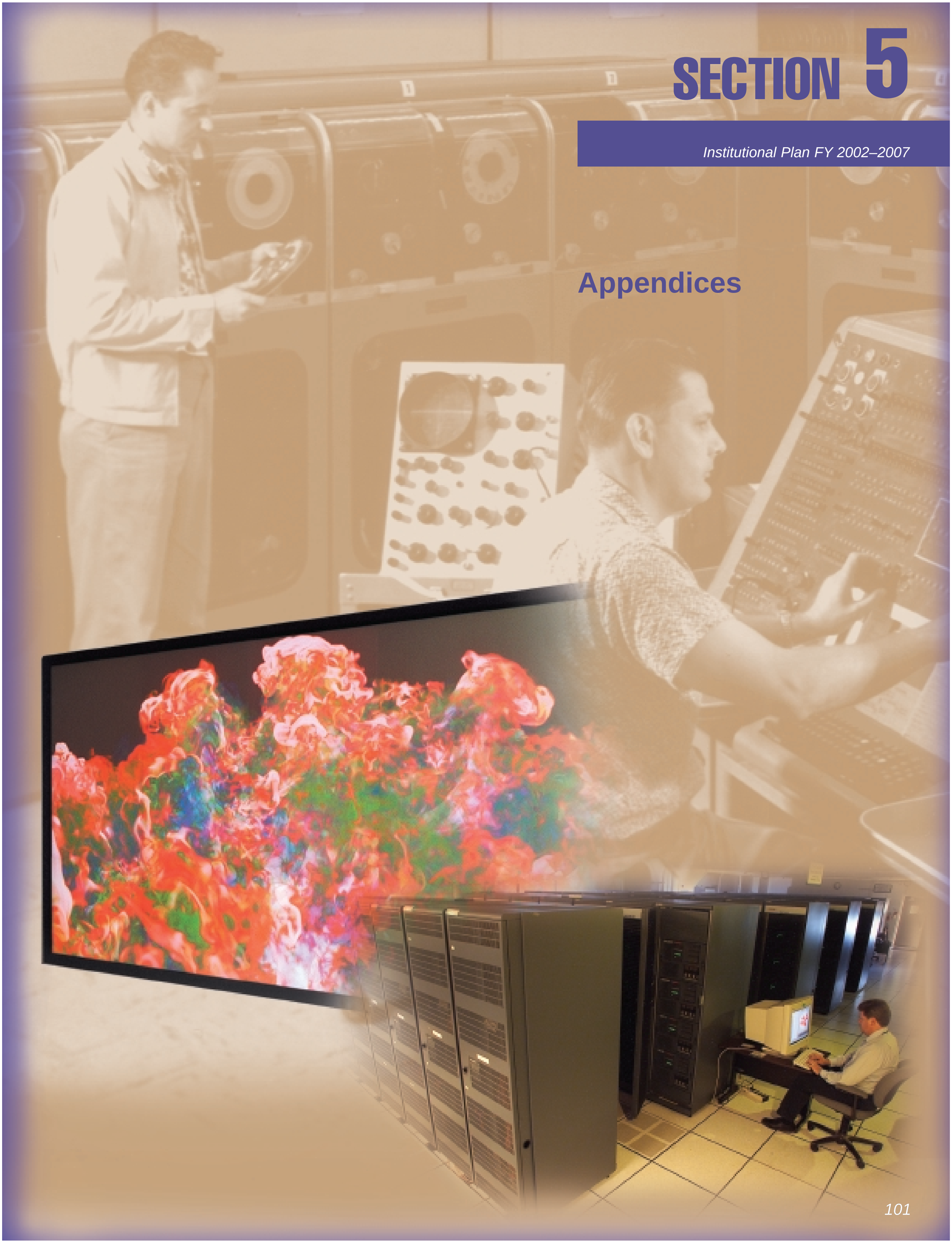
The Laboratory also hosted a "Science Day" on March 21, 2001, which showcased our supercomputer-assisted research as well as other crowning achievements in science and technology. The community and all employees were invited, and opening comments were provided by the Laboratory director, NNSA Administrator John Gordon, and UC Provost and Senior Vice President C. Judson King.

In addition, as a Superfund site, Livermore participates in a national program on health assessment conducted by the Agency for Toxic Substances and Disease Registry. We are involved in community meetings focused on public health issues about Laboratory environmental restoration activities and operations. We publish a newsletter and offer a Web site on these topics, and we frequently respond to questions from students, members of the general public, homebuyers, and realtors.

Among the many other interactions the Laboratory has with the local community is our effort to establish Consolidated Fire Dispatch with various communities within the County of Alameda. A regional dispatch center at the Laboratory would serve a number of municipal fire departments, the Laboratory's Fire Department, and the Alameda County Emergency Medical Services Agency. Other organizations will be attracted to join after they see the advantages to the system. The establishment of a consolidated dispatch center will entail expanding into the space currently occupied by the Emergency Management Center, which shares Building 313. We will be moving the Emergency Management Center into Building 323 as a temporary measure and have proposed the construction of a new building to house this function.

SECTION 5

Appendices



5.1 Program Resource Requirement Projections

Data for FY 2000 are taken from the *FY 2000 LLNL Budget Office Annual Report*. Data for FY 2001 through FY 2003 represent a combination of the FY 2003 Field Budget Submission (for non-Defense Programs) and the FY 2003–2004 Defense Programs Field Budget Estimates (April 2001). The guidance case is used for all programs. The resource data for FY 2000 through 2007 are based on the following:

- FY 2000 and FY 2001: actual budget obligations and authority (BO and BA), respectively.
- FY 2002 through FY 2007: program managers' estimates of resource requirements.
- Inflation factor: for FY 2002 and FY 2003, 2.1% escalation for operating expenses and 4.5% for pay and personnel.
- For years beyond FY 2003, resources requirements are expressed in constant FY 2003 dollars except for Defense Programs. Defense Programs outyear budgets are program managers' estimates of resource requirements.

The program resource projections are shown as follows:

- Tables 5.1-1 and 5.1-2. Laboratory funding and personnel summaries.
- Tables 5.1-3 and 5.1-4. Resources and personnel by major DOE program.
- Tables 5.1-5 through 5.1-22. Detailed resource breakouts by DOE sponsors.
- Table 5-2. Provides data about small and disadvantaged business procurement.

Table 5.1-1. Laboratory funding summary (in millions of dollars, $M).

	FY 2000 BO	FY 2001 BO	FY 2002[a] BA	FY 2003[a] BA	FY 2004[b] BA	FY 2005[b] BA	FY 2006[b] BA	FY 2007[b] BA
DOE Effort[c]	801.8	860.3	937.8	1033.8	1126.2	1179.1	1206.3	1276.8
Work for Others–DOE Facilities and Field Offices	84.0	85.7	105.6	96.0	96.0	96.0	96.0	96.0
Work-for-Others–Non-DOE	152.5	131.0	187.9	196.8	196.8	196.8	196.8	196.8
Total Operating	1038.3	1077.0	1231.3	1326.6	1419.1	1419.1	1419.1	1419.1
Program Capital Equipment	2.7	14.0	1.2	1.1	1.1	1.1	1.1	1.3
Program Construction	283.9	280.2	314.8	294.8	202.0	172.4	170.0	122.9
General Purpose Facilities	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	7.3	1.8	0.4	2.2	2.2	2.2	2.2	2.2
Total Projected Funding	1332.2	1373.0	1547.9	1625.0	1618.7	1624.9	1647.7	1696.1
Institutional General Purpose Equipment	8.7	7.7	8.0	8.4	8.4	8.4	8.4	8.4
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a]For FY 2002 and 2003, escalation of 2.1% for operating expenses and 4.5% for pay and personnel-related items.
[b]FY 2004 and beyond in constant FY 2003 dollars except for Defense Programs, which provided plans through FY 2007.
[c]Excludes DOE Field Offices and reimbursable work for others.

Table 5.1-2. Laboratory personnel summary (in full-time employee equivalent, or FTE).

	FY 2000 BO	FY 2001 BO	FY 2002 BA	FY 2003 BA	FY 2004 BA	FY 2005 BA	FY 2006 BA	FY 2007 BA
Direct								
DOE Effort	2670.7	3025.0	3370.6	3375.0	3450.8	3462.7	3508.7	3536.7
Work-for-Others–Facilities and Field Offices	289.2	251.0	294.0	250.0	250.0	250.0	250.0	250.0
Work for Others–Non-DOE	416.4	354.2	560.0	550.0	550.0	550.0	550.0	550.0
Total Direct	3376.3	3630.2	4233.6	4175.0	4250.8	4262.7	4308.7	4336.7
Total Indirect	3851.2	3461.6	3041.4	3100.0	3024.2	3037.3	3016.3	3016.8
Total Personnel	7227.5	7091.8	7275.0	7275.0	7275.0	7300.0	7325.0	7353.0

Table 5.1-3. Funding by Secretarial Officer; resources by major program (in $M; personnel in FTEs).

Major Program	FY 2000 BO	FY 2001 BO	FY 2002[a] BA	FY 2003[a] BA	FY 2004[b] BA	FY 2005[b] BA	FY 2006[b] BA	FY 2007[b] BA
Defense Programs								
Operating Costs	539.1	610.9	663.1	747.3	833.7	869.6	894.8	990.3
Capital Equipment	1.9	12.4	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	7.2	1.8	0.0	0.0	0.0	0.0	0.0	0.0
Construction	278.6	274.2	314.1	294.7	202.0	172.4	170.0	122.9
Total Cost/Funding	826.8	899.3	977.2	1042.0	1035.7	1042.0	1064.8	1113.2
Direct Personnel	1849.9	2310.6	2520.2	2520.2	2596.0	2607.9	2653.9	2681.9
Security & Emergency Operations								
Operating Costs	20.9	20.8	10.8	11.6	11.6	11.6	11.6	11.6
Capital Equipment	0.2	0.4	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	21.1	21.2	10.8	11.6	11.6	11.6	11.6	11.6
Direct Personnel	59.1	53.3	29.3	25.8	25.8	25.8	25.8	25.8
Defense Nuclear Nonproliferation								
Operating Costs	108.8	100.5	102.5	107.5	107.5	107.5	107.5	107.5
Capital Equipment	0.0	0.3	0.7	0.7	0.7	0.7	0.7	0.7
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	108.8	100.8	103.2	108.2	108.2	108.2	108.2	108.2
Direct Personnel	265.5	225.7	222.6	227.7	227.7	227.7	227.7	227.7
Intelligence								
Operating Costs	4.5	3.8	5.5	6.3	6.3	6.3	6.3	6.3
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	4.5	5.3	5.5	6.3	6.3	6.3	6.3	6.3
Direct Personnel	14.6	12.6	20.2	21.5	21.5	21.5	21.5	21.5
Counterintelligence								
Operating Costs	3.0	3.5	5.0	5.2	5.2	5.2	5.2	5.2
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	3.0	3.5	5.0	5.2	5.2	5.2	5.2	5.2
Direct Personnel	11.9	11.6	20.5	20.5	20.5	20.5	20.5	20.5
Science								
Operating Costs	61.2	53.3	68.6	68.7	68.7	68.7	68.7	68.7
Capital Equipment	0.5	0.9	0.7	0.6	0.6	0.6	0.6	0.6
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	61.6	54.2	69.3	69.3	69.3	69.3	69.3	69.3
Direct Personnel	215.8	189.7	283.8	273.4	273.4	273.4	273.4	273.4

Table 5.1-3, continued. Funding by Secretarial Officer; resources by major program (in $M; personnel in FTEs).

Major Program	FY 2000 BO	FY 2001 BO	FY 2002[a] BA	FY 2003[a] BA	FY 2004[b] BA	FY 2005[b] BA	FY 2006[b] BA	FY 2007[b] BA
Environmental Management								
Operating Costs	49.3	45.7	48.4	53.1	53.1	53.1	53.1	53.1
Capital Equipment	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.1	0.0	0.4	2.2	2.2	2.2	2.2	2.2
Construction	5.3	4.3	0.7	0.1	0.0	0.0	0.0	0.0
Total Cost/Funding	54.8	50.0	49.5	55.4	55.3	55.3	55.3	55.3
Direct Personnel	210.1	188.1	208.7	213.0	213.0	213.0	213.0	213.1
Environment, Safety, & Health								
Operating Costs	3.1	2.8	3.0	3.1	3.1	3.1	3.1	3.1
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	3.1	2.8	3.0	3.1	3.1	3.1	3.1	3.1
Direct Personnel	9.5	7.7	7.8	7.8	7.8	7.8	7.8	7.8
Nuclear Energy, Science, and Technology								
Operating Costs	0.6	0.5	1.4	1.1	1.1	1.1	1.1	1.1
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.6	0.5	1.4	1.1	1.1	1.1	1.1	1.1
Direct Personnel	2.3	1.3	8.9	7.5	7.5	7.5	7.5	7.5
Naval Reactors								
Operating Costs	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Direct Personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fossil Energy								
Operating Costs	2.7	2.7	5.8	4.6	4.6	4.6	4.6	4.6
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	2.7	2.7	5.8	4.6	4.6	4.6	4.6	4.6
Direct Personnel	7.1	7.2	22.2	18.9	18.9	18.9	18.9	18.9
Energy Efficiency & Renewable Energy								
Operating Costs	7.7	6.3	9.5	10.7	10.7	10.7	10.7	10.7
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	7.7	6.5	9.5	10.7	10.7	10.7	10.7	10.7
Direct Personnel	23.2	16.8	33.2	36.5	36.5	36.5	36.5	36.5

Table 5.1-3, continued. Funding by Secretarial Officer; resources by major program (in $M; personnel in FTEs).

Major Program	FY 2000 BO	FY 2001 BO	FY 2002[a] BA	FY 2003[a] BA	FY 2004[b] BA	FY 2005[b] BA	FY 2006[b] BA	FY 2007[b] BA
Management & Administration								
Operating Costs	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Policy								
Operating Costs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Civilian Radioactive Waste Management								
Operating Costs	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Direct Personnel	0.3	0.4	2.1	2.1	2.1	2.1	2.1	2.1
Chief Financial Officer								
Operating Costs	0.0	9.0	13.7	14.1	14.1	14.1	14.1	14.1
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.0	9.0	13.7	14.1	14.1	14.1	14.1	14.1
Direct Personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WFO DOE Facilities/Field Offices								
Operating Costs	84.0	85.7	105.6	96.0	96.0	96.0	96.0	96.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	84.0	85.7	105.6	96.0	96.0	96.0	96.0	96.0
Direct Personnel	289.2	251.0	294.0	250.0	250.0	250.0	250.0	250.0
Total DOE Programs								
Operating Costs	885.8	946.0	1043.4	1129.8	1222.3	1275.1	1302.3	1372.8
Capital Equipment	2.7	14.0	1.4	1.3	1.3	1.3	1.3	1.3
General Plant Projects	7.3	1.8	0.4	2.2	2.2	2.2	2.2	2.2
Construction	283.9	280.2	314.8	294.8	196.0	149.4	145.0	122.9
Total Cost/Funding	1179.7	1242.0	1360.6	1428.2	1421.9	1428.1	1450.9	1499.3
Direct Personnel	2959.9	3276.0	3673.6	3625.0	3700.8	3712.7	3758.7	3786.7

Table 5.1-3, continued. Funding by Secretarial Officer; resources by major program (in $M; personnel in FTEs).

Major Program	FY 2000 BO	FY 2001 BO	FY 2002[a] BA	FY 2003[a] BA	FY 2004[b] BA	FY 2005[b] BA	FY 2006[b] BA	FY 2007[b] BA
Work-for-Others/Non-DOE								
Operating Costs	152.5	129.6	190.5	199.4	199.4	199.4	199.4	199.4
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	152.5	131.0	187.9	196.8	196.8	196.8	196.8	196.8
Direct Personnel	416.4	354.2	560.0	550.0	550.0	550.0	550.0	550.0
Total Program Funding								
Operating Costs	1038.3	1075.6	1233.9	1329.2	1421.7	1474.5	1501.7	1572.2
Capital Equipment	2.7	14.0	1.4	1.1	1.3	1.3	1.3	1.3
General Plant Projects	7.3	1.8	0.4	2.2	2.2	2.2	2.2	2.2
Construction	283.9	280.2	314.8	294.8	196.0	149.4	145.0	122.9
Total Cost/Funding	1332.2	1373.0	1547.9	1625.0	1618.7	1624.9	1647.7	1696.1
Direct Personnel	3376.3	3630.2	4233.6	4175.0	4250.8	4262.7	4308.7	4336.7
Institutional General Purpose Equipment[c]	8.7	7.7	8.0	8.4	8.4	8.4	8.4	8.4
General Purpose Facilities[d]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a]For FY 2002 and FY 2003, 2.1% escalation for operating expenses and 4.5% for pay and personnel-related items.
[b]FY 2004 and beyond in constant FY 2003 dollars except for Defense Programs, which provided plans through FY 2007.
[c]Institutional General Purpose Equipment (IGPE) amounts represent unloaded costs.
[d]LLNL does not have any General Purpose Facilities.

Table 5.1-4. Personnel by Secretarial Officer (personnel in FTEs).

Major Program	FY 2000 BO	FY 2001 BO	FY 2002 BA	FY 2003 BA	FY 2004 BA	FY 2005 BA	FY 2006 BA	FY 2007 BA
Defense Programs								
Operating	1360.9	1839.7	1855.4	1956.1	2181.0	2304.1	2323.5	2401.5
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	489.0	470.8	664.8	564.1	415.0	303.8	330.4	280.4
Total FTEs	1849.9	2310.6	2520.2	2520.2	2596.0	2607.9	2653.9	2681.9
Security & Emergency Operations								
Operating	59.1	53.3	29.3	25.8	25.8	25.8	25.8	25.8
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total FTEs	59.1	53.3	29.3	25.8	25.8	25.8	25.8	25.8
Defense Nuclear Nonproliferation								
Operating	265.5	225.7	222.6	227.7	227.7	227.7	227.7	227.7
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total FTEs	265.5	225.7	222.6	227.7	227.7	227.7	227.7	227.7
Intelligence								
Operating	14.6	12.6	20.2	21.5	21.5	21.5	21.5	21.5
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total FTEs	14.6	12.6	20.2	21.5	21.5	21.5	21.5	21.5
Counterintelligence								
Operating	11.9	11.6	20.5	20.5	20.5	20.5	20.5	20.5
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total FTEs	11.9	11.6	20.5	20.5	20.5	20.5	20.5	20.5
Science								
Operating	215.8	189.7	283.8	273.4	273.4	273.4	273.4	273.4
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total FTEs	215.8	189.7	283.8	273.4	273.4	273.4	273.4	273.4
Environmental Management								
Operating	210.1	188.1	208.8	213.1	213.1	213.1	213.1	213.1
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total FTEs	210.1	188.1	208.8	213.1	213.1	213.1	213.1	213.1
Environment, Safety, & Health								
Operating	9.5	7.7	7.8	7.8	7.8	7.8	7.8	7.8
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total FTEs	9.5	7.7	7.8	7.8	7.8	7.8	7.8	7.8

Table 5.1-4, continued. Personnel by Secretarial Officer (personnel in FTEs).

Major Program	FY 2000 BO	FY 2001 BO	FY 2002 BA	FY 2003 BA	FY 2004 BA	FY 2005 BA	FY 2006 BA	FY 2007 BA
Nuclear Energy								
Operating	2.3	1.3	8.9	7.5	7.5	7.5	7.5	7.5
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total FTEs	2.3	1.3	8.9	7.5	7.5	7.5	7.5	7.5
Naval Reactors								
Operating	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total FTEs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fossil Energy								
Operating	7.1	7.2	22.2	18.9	18.9	18.9	18.9	18.9
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total FTEs	7.1	7.2	22.2	18.9	18.9	18.9	18.9	18.9
Energy Efficiency & Renewable Energy								
Operating	23.2	16.8	33.2	36.5	36.5	36.5	36.5	36.5
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total FTEs	23.2	16.8	33.2	36.5	36.5	36.5	36.5	36.5
Management & Administration								
Operating	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total FTEs	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Policy								
Operating	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total FTEs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Civilian Radioactive Waste Management								
Operating	0.3	0.4	2.1	2.1	2.1	2.1	2.1	2.1
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total FTEs	0.3	0.4	2.1	2.1	2.1	2.1	2.1	2.1

Table 5.1-4, continued. Personnel by Secretarial Officer (personnel in FTEs).

Major Program	FY 2000 BO	FY 2001 BO	FY 2002 BA	FY 2003 BA	FY 2004 BA	FY 2005 BA	FY 2006 BA	FY 2007 BA
Chief Financial Officer								
Operating	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects[a]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total FTEs[b]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WFO DOE Facilities/Field Offices								
Operating	289.2	251.0	294.0	250.0	250.0	250.0	250.0	250.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total FTEs	289.2	251.0	294.0	250.0	250.0	250.0	250.0	250.0
Total DOE Programs								
Operating	2470.9	2805.1	3008.8	3060.9	3285.8	3408.9	3428.3	3506.3
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	489.0	470.8	664.8	564.1	415.0	303.8	330.4	280.4
Total FTEs	2959.9	3276.0	3673.6	3625.0	3700.8	3712.7	3758.7	3786.7
Work-for-Others/Non-DOE								
Operating	416.4	354.2	560.0	550.0	550.0	550.0	550.0	550.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total FTEs	416.4	354.2	560.0	550.0	550.0	550.0	550.0	550.0
Total Program Effort								
Operating	2887.3	3159.3	3568.8	3610.9	3835.8	3958.9	3978.3	4056.3
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	489.0	470.8	664.8	564.1	415.0	303.8	330.4	280.4
Total FTEs	3376.3	3630.2	4233.6	4175.0	4250.8	4262.7	4308.7	4336.7
General Purpose Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Purpose Facilities	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Direct Personnel	3376.3	3630.2	4233.6	4175.0	4250.8	4262.7	4308.7	4336.7
Total Indirect Personnel	3851.2	3461.6	3041.4	3100.0	3024.2	3037.3	3016.3	3016.3
Total Laboratory Personnel	7227.5	7091.8	7275.0	7275.0	7275.0	7300.0	7325.0	7353.0

[a]FTE level for General Plant Projects is included in Construction estimates.
[b]FTEs for WN05 are included in B&R FS — Safeguards and Security in Defense Programs.

Table 5.1-5. Defense Programs detailed resource breakout by program element (in $M; personnel in FTEs).

Major Program	FY 2000[c] BO	FY 2001 BO	FY 2002[a] BA	FY 2003[a] BA	FY 2004[b] BA	FY 2005[b] BA	FY 2006[b] BA	FY 2007[b] BA
Program Direction–DP05								
Operating Costs	1.3	0.8	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	1.3	0.8	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	1.6	0.5	0.0	0.0	0.0	0.0	0.0	0.0
Directed Stockpile Work–DP07								
Operating Costs	41.8	58.2	77.5	95.5	114.4	112.4	111.5	115.9
Capital Equipment	0.2	0.5	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	42.0	59.8	77.5	95.5	114.4	112.4	111.5	115.9
Direct Personnel	102.1	186.2	246.8	251.4	347.9	341.8	339.1	342.2
Campaigns–DP08 (except DP0810)								
Operating Costs	352.0	325.3	329.8	368.0	360.2	383.1	401.7	453.2
Capital Equipment	0.9	10.8	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	1.9	0.5	0.0	0.0	0.0	0.0	0.0	0.0
Construction	5.7	8.0	41.9	38.3	36.8	16.4	15.0	0.0
Total Cost/Funding	360.5	344.6	371.7	406.3	397.0	399.5	416.7	453.2
Direct Personnel	886.9	741.0	823.2	821.4	848.0	854.6	891.4	935.6
ICF/Ignition High-Yield Campaign/National Ignition Facility–DP0810								
Operating Costs	101.1	114.6	104.6	118.6	156.2	182.0	187.2	193.9
Capital Equipment	0.7	0.2	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	248.2	251.5	245.0	214.0	150.0	130.0	130.0	120.0
Total Cost/Funding	350.3	366.3	349.6	332.6	306.2	312.0	317.2	313.9
Direct Personnel	732.6	742.3	760.4	721.7	731.1	745.0	757.4	722.6
Readiness in Technical Base & Facilities (RTBF)–DP09								
Operating Costs	42.9	49.5	53.1	53.4	63.3	68.5	71.3	76.2
Capital Equipment	0.1	0.4	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	5.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Construction	24.7	13.3	27.2	42.4	9.2	3.0	0.0	2.9
Total Cost/Funding	72.7	63.4	80.3	95.8	72.5	71.5	71.3	79.1
Direct Personnel	126.7	190.9	236.6	260.4	203.7	201.2	200.7	216.2
NNSA Facilities & Infrastructure[d]								
Operating Costs	0.0	0.3	14.3	17.7	50.0	50.0	50.0	50.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.0	0.3	14.3	50.0	50.0	50.0	50.0	50.0
Direct Personnel[e]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 5.1-5, continued. Defense Programs detailed resource breakout by program element (in $M; personnel in FTEs).

Major Program	FY 2000[c] BO	FY 2001 BO	FY 2002[a] BA	FY 2003[a] BA	FY 2004[b] BA	FY 2005[b] BA	FY 2006[b] BA	FY 2007[b] BA
Cerro Grande Fire Activities (DARHT)–CG								
Operating Costs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	1.4	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.0	1.4	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	0.0	11.3	0.0	0.0	0.0	0.0	0.0	0.0
Safeguards & Security-NNSA–FS[f]								
Operating Costs	0.0	62.2	83.8	94.1	95.7	96.6	98.1	101.1
Capital Equipment	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.0	62.7	83.8	94.1	95.7	96.6	98.1	101.1
Direct Personnel	0.0	438.4	453.2	465.3	465.3	465.3	465.3	465.3
Total Defense Programs								
Operating Costs	539.1	610.9	663.1	747.3	839.8	892.6	919.8	990.3
Capital Equipment	1.9	12.4	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects[g]	7.2	1.8	0.0	0.0	0.0	0.0	0.0	0.0
Construction	278.6	274.2	314.1	294.7	196.0	149.4	145.0	122.9
Total Cost/Funding	826.8	899.3	977.2	1042.0	1035.8	1042.0	1064.8	1113.2
Direct Personnel	1849.9	2310.6	2520.2	2520.2	2596.0	2607.9	2653.9	2681.9
General Purpose Facilities	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a]For FY 2002 and FY 2003, 2.1% escalation for operating expenses and 4.5% for pay and personnel-related items.
[b]FY 2004 and beyond in constant FY 2003 dollars.
[c]FY 2000 data were recast to current B&R structure.
[d]This is a new program beginning in 2002, budget dollars per guidance.
[e]Not available at this time.
[f]FY 2001 is the first year for direct funding of Safeguards & Security.
[g]The DP Budget Submission did not differentiate General Plant Projects in FY 2001 and FY 2007.

Table 5.1-6. Security and Emergency Operations detailed resource breakout by program element (in $M; personnel in FTEs).

Major Program	FY 2000 BO	FY 2001 BO	FY 2002[a] BA	FY 2003[a] BA	FY 2004[b] BA	FY 2005[b] BA	FY 2006[b] BA	FY 2007[b] BA
Office of Security & Emergency Operations–SO								
Operating Costs	10.3	7.1	5.9	6.1	6.1	6.1	6.1	6.1
Capital Equipment	0.1	0.3	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	10.4	7.4	5.9	6.1	6.1	6.1	6.1	6.1
Direct Personnel	26.7	15.7	11.6	11.6	11.6	11.6	11.6	11.6
Emergency Management–ND								
Operating Costs	0.8	0.5	0.4	0.4	0.4	0.4	0.4	0.4
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.8	0.5	0.4	0.4	0.4	0.4	0.4	0.4
Direct Personnel	0.8	0.2	1.1	1.1	1.1	1.1	1.1	1.1
Nuclear Safeguards & Security–GD								
Operating Costs	9.8	13.2	4.5	5.1	5.1	5.1	5.1	5.1
Capital Equipment	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	9.9	13.3	4.5	5.1	5.1	5.1	5.1	5.1
Direct Personnel	31.6	37.4	16.6	13.1	13.1	13.1	13.1	13.1
Total Security & Emergency Operations								
Operating Costs	20.9	20.8	10.8	11.6	11.6	11.6	11.6	11.6
Capital Equipment	0.2	0.4	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	21.1	21.2	10.8	11.6	11.6	11.6	11.6	11.6
Direct Personnel	59.1	53.3	29.3	25.8	25.8	25.8	25.8	25.8
General Purpose Facilities	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a]For FY 2002 and FY 2003, 2.1% escalation for operating expenses and 4.5% for pay and personnel-related items.
[b]FY 2004 and beyond in constant FY 2003 dollars.

Table 5.1-7. Defense Nuclear Nonproliferation detailed resource breakout by program element (in $M; personnel in FTEs).

Major Program	FY 2000 BO	FY 2001 BO	FY 2002[a] BA	FY 2003[a] BA	FY 2004[b] BA	FY 2005[b] BA	FY 2006[b] BA	FY 2007[b] BA
Defense Nuclear Nonproliferation–NN								
Operating Costs	108.8	100.5	102.5	107.5	107.5	107.5	107.5	107.5
Capital Equipment	0.0	0.3	0.7	0.7	0.7	0.7	0.7	0.7
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	108.8	100.8	103.2	108.2	108.2	108.2	108.2	108.2
Direct Personnel	265.5	225.7	222.6	227.7	227.7	227.7	227.7	227.7
General Purpose Facilities	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a]For FY 2002 and FY 2003, 2.1% escalation for operating expenses and 4.5% for pay and personnel-related items.
[b]FY 2004 and beyond in constant FY 2003 dollars.

Table 5.1-8. Intelligence detailed resource breakout by program element (in $M; personnel in FTEs).

Major Program	FY 2000 BO	FY 2001 BO	FY 2002[a] BA	FY 2003[a] BA	FY 2004[b] BA	FY 2005[b] BA	FY 2006[b] BA	FY 2007[b] BA
Intelligence–IN								
Operating Costs	4.5	3.8	5.5	6.3	6.3	6.3	6.3	6.3
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	4.5	5.3	5.5	6.3	6.3	6.3	6.3	6.3
Direct Personnel	14.6	12.6	20.2	21.5	21.5	21.5	21.5	21.5
General Purpose Facilities	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a]For FY 2002 and FY 2003, 2.1% escalation for operating expenses and 4.5% for pay and personnel-related items.
[b]FY 2004 and beyond in constant FY 2003 dollars.

Table 5.1-9. Counterintelligence detailed resource breakout by program element (in $M; personnel in FTEs).

Major Program	FY 2000 BO	FY 2001 BO	FY 2002[a] BA	FY 2003[a] BA	FY 2004[b] BA	FY 2005[b] BA	FY 2006[b] BA	FY 2007[b] BA
Counterintelligence–CN								
Operating Costs	3.0	3.5	5.0	5.2	5.2	5.2	5.2	5.2
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	3.0	3.5	5.0	5.2	5.2	5.2	5.2	5.2
Direct Personnel	11.9	11.6	20.5	20.5	20.5	20.5	20.5	20.5
General Purpose Facilities	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a]For FY 2002 and FY 2003, 2.1% escalation for operating expenses and 4.5% for pay and personnel-related items.
[b]FY 2004 and beyond in constant FY 2003 dollars.

Table 5.1-10. Science detailed resource breakout by program element (in $M; personnel in FTEs).

Major Program	FY 2000 BO	FY 2001 BO	FY 2002[a] BA	FY 2003[a] BA	FY 2004[b] BA	FY 2005[b] BA	FY 2006[b] BA	FY 2007[b] BA
Program Direction–Safeguards & Security–FS15								
Operating Costs	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Life Sciences–KP11								
Operating Costs	26.2	20.4	22.9	22.6	22.6	22.6	22.6	22.8
Capital Equipment	0.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	26.5	20.7	22.9	22.6	22.6	22.6	22.6	22.6
Direct Personnel	111.7	91.5	131.2	125.8	125.8	125.8	125.8	125.8
Environmental Processes–KP12								
Operating Costs	6.9	7.0	9.6	9.3	9.3	9.3	9.3	9.3
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	6.9	7.0	9.6	9.3	9.3	9.3	9.3	9.3
Direct Personnel	21.9	23.4	31.2	29.0	29.0	29.0	29.0	29.0
Medical Applications & Measurement Science–KP14								
Operating Costs	1.1	1.2	0.2	0.2	0.2	0.2	0.2	0.2
Capital Equipment	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	1.2	7.0	0.2	0.2	0.2	0.2	0.2	0.2
Direct Personnel	3.2	23.4	0.7	0.7	0.7	0.7	0.7	0.7
Fusion Energy Sciences–AT								
Operating Costs	15.2	14.6	15.3	15.3	15.3	15.3	15.3	15.3
Capital Equipment	–0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	15.1	14.7	15.3	15.3	15.3	15.3	15.3	15.3
Direct Personnel	53.3	49.3	54.3	51.2	51.2	51.2	51.2	51.2
Materials Sciences–KC02								
Operating Costs	3.4	2.9	4.6	4.8	4.8	4.8	4.8	4.8
Capital Equipment	0.1	0.4	0.3	0.3	0.3	0.3	0.3	0.3
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	3.5	3.3	4.9	5.1	5.1	5.1	5.1	5.1
Direct Personnel	6.2	5.0	14.0	14.0	14.0	14.0	14.0	14.0

Table 5.1-10, continued. Science detailed resource breakout by program element (in $M; personnel in FTEs).

Major Program	FY 2000 BO	FY 2001 BO	FY 2002[a] BA	FY 2003[a] BA	FY 2004[b] BA	FY 2005[b] BA	FY 2006[b] BA	FY 2007[b] BA
Chemical Sciences–KC03								
Operating Costs	0.7	0.6	0.7	0.7	0.7	0.7	0.7	0.7
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.7	0.6	0.7	0.7	0.7	0.7	0.7	0.7
Direct Personnel	1.9	1.1	2.5	2.1	2.1	2.1	2.1	2.1
Engineering and Geosciences–KC04								
Operating Costs	1.8	1.4	1.9	1.9	1.9	1.9	1.9	1.9
Capital Equipment	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	1.9	1.5	2.0	1.9	1.9	1.9	1.9	1.9
Direct Personnel	5.6	4.3	6.5	6.5	6.5	6.5	6.5	6.5
Math, Information, and Computation Science–KJ01								
Operating Costs	3.6	3.4	9.7	10.3	10.3	10.3	10.3	10.3
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	3.6	3.4	9.7	10.3	10.3	10.3	10.3	10.3
Direct Personnel	9.3	9.5	27.5	27.7	27.7	27.7	27.7	27.7
Research and Technology–KA04								
Operating Costs	1.4	1.1	2.8	2.7	2.7	2.7	2.7	2.7
Capital Equipment	0.0	0.0	0.3	0.3	0.3	0.3	0.3	0.3
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	1.4	1.1	3.1	3.0	3.0	3.0	3.0	3.0
Direct Personnel	1.5	1.2	11.1	11.4	11.4	11.4	11.4	11.4
Heavy-Ion Physics–KB02								
Operating Costs	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding[c]	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nuclear Theory–KB03								
Operating Costs	0.2	0.1	0.3	0.3	0.3	0.3	0.3	0.3
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.2	0.1	0.3	0.3	0.3	0.3	0.3	0.3
Direct Personnel	0.3	0.3	1.5	1.5	1.5	1.5	1.5	1.5

Table 5.1-10, continued. Science detailed resource breakout by program element (in $M; personnel in FTEs).

Major Program	FY 2000 BO	FY 2001 BO	FY 2002[a] BA	FY 2003[a] BA	FY 2004[b] BA	FY 2005[b] BA	FY 2006[b] BA	FY 2007[b] BA
Low-Energy Physics–KB04								
Operating Costs	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Direct Personnel	0.9	1.0	3.3	3.5	3.5	3.5	3.5	3.5
Total Science								
Operating Costs	61.2	53.3	68.6	68.7	68.7	68.7	68.7	68.7
Capital Equipment	0.5	0.9	0.7	0.6	0.6	0.6	0.6	0.6
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	61.6	54.2	69.3	69.3	69.3	69.3	69.3	69.3
Direct Personnel	215.8	189.7	283.8	273.4	273.4	273.4	273.4	273.4
General Purpose Facilities	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a]For FY 2002 and FY 2003, 2.1% escalation for operating expenses and 4.5% for pay and personnel-related items.
[b]FY 2004 and beyond in constant FY 2003 dollars.
[c]Costs are under $50,000.

Table 5.1-11. Environmental Restoration and Waste Management detailed resource breakout by program element (in $M; personnel in FTEs).

Major Program	FY 2000 BO	FY 2001 BO	FY 2002[a] BA	FY 2003[a] BA	FY 2004[b] BA	FY 2005[b] BA	FY 2006[b] BA	FY 2007[b] BA
Post 2006 Completion–EW02								
Operating Costs	0.6	40.2	43.8	48.2	48.2	48.2	48.2	48.2
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.4	2.2	2.2	2.2	2.2	2.2
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.6	40.2	44.2	50.4	50.4	50.4	50.4	50.4
Direct Personnel	2.5	174.4	190.2	194.9	194.9	194.9	194.9	194.9
Site/Project Completion–EW04								
Operating Costs	43.6	2.1	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	5.3	4.3	0.7	0.1	0.0	0.0	0.0	0.0
Total Cost/Funding	43.7	6.4	0.7	0.1	0.0	0.0	0.0	0.0
Direct Personnel	191.3	2.1	0.8	0.0	0.0	0.0	0.0	0.0
Program Direction (Defense)–EW10								
Operating Costs	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Technology Development–EW40								
Operating Costs	3.7	1.5	2.7	2.9	2.9	2.9	2.9	2.9
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	3.7	1.5	2.7	2.9	2.9	2.9	2.9	2.9
Direct Personnel	10.0	4.3	9.8	10.1	10.1	10.1	10.1	10.1
Post 2006 Completion–EX02								
Operating Costs	1.3	1.7	1.7	1.8	1.8	1.8	1.8	1.8
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	1.3	1.7	1.7	1.8	1.8	1.8	1.8	1.8
Direct Personnel	6.3	7.2	7.9	8.0	8.0	8.0	8.0	8.0
Site/Project Completion–EX04								
Operating Costs	0.0	0.1	0.2	0.2	0.2	0.2	0.2	0.2
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.0	0.1	0.2	0.2	0.2	0.2	0.2	0.2
Direct Personnel	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1

Table 5.1-11, continued. Environmental Restoration and Waste Management detailed resource breakout by program element (in $M; personnel in FTEs).

Major Program	FY 2000 BO	FY 2001 BO	FY 2002[a] BA	FY 2003[a] BA	FY 2004[b] BA	FY 2005[b] BA	FY 2006[b] BA	FY 2007[b] BA
Total Environmental Restoration & Waste Management								
Operating Costs	49.3	45.7	48.4	53.1	53.1	53.1	53.1	53.1
Capital Equipment	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.1	0.0	0.4	2.2	2.2	2.2	2.2	2.2
Construction	5.3	4.3	0.7	0.1	0.0	0.0	0.0	0.0
Total Cost/Funding	54.8	50.0	49.5	55.4	55.3	55.3	55.3	55.3
Direct Personnel[c]	210.1	188.1	208.8	213.1	213.1	213.1	213.1	213.1
General Purpose Facilities	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a]For FY 2002 and FY 2003, 2.1% escalation for operating expenses and 4.5% for pay and personnel-related items.
[b]FY 2004 and beyond in constant FY 2003 dollars.
[c]FTEs for Construction are provided through indirect staffing.

Table 5.1-12. Environment, Safety & Health detailed resource breakout by program element (in $M; personnel in FTEs).

Major Program	FY 2000 BO	FY 2001 BO	FY 2002[a] BA	FY 2003[a] BA	FY 2004[b] BA	FY 2005[b] BA	FY 2006[b] BA	FY 2007[b] BA
Line Management Support–HC11								
Operating Costs	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Direct Personnel	0.8	0.6	0.5	0.5	0.5	0.5	0.5	0.5
Health Studies–HD20								
Operating Costs	2.9	2.6	2.8	2.9	2.9	2.9	2.9	2.9
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	2.9	2.6	2.8	2.9	2.9	2.9	2.9	2.9
Direct Personnel	8.7	7.1	7.3	7.3	7.3	7.3	7.3	7.3
Total Environment, Safety, & Health								
Operating Costs	3.1	2.8	3.0	3.1	3.1	3.1	3.1	3.1
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	3.1	2.8	3.0	3.1	3.1	3.1	3.1	3.1
Direct Personnel	9.5	7.7	7.8	7.8	7.8	7.8	7.8	7.8
General Purpose Facilities	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a]For FY 2002 and FY 2003, 2.1% escalation for operating expenses and 4.5% for pay and personnel-related items.
[b]FY 2004 and beyond in constant FY 2003 dollars.

Table 5.1-13. Nuclear Energy, Science and Technology detailed resource breakout by program element (in $M; personnel in FTEs).

Major Program	FY 2000 BO	FY 2001 BO	FY 2002[a] BA	FY 2003[a] BA	FY 2004[b] BA	FY 2005[b] BA	FY 2006[b] BA	FY 2007[b] BA
Nuclear Research & Development–AF								
Operating Costs	0.2	0.5	1.4	1.1	1.1	1.1	1.1	1.1
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.2	0.5	1.4	1.1	1.1	1.1	1.1	1.1
Direct Personnel	0.7	1.2	8.7	7.3	7.3	7.3	7.3	7.3
Conversion Project–CD1017								
Operating Costs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Program Direction–Nuclear Energy–KK05								
Operating Costs	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding[c]	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	1.4	0.1	0.2	0.2	0.2	0.2	0.2	0.2
Total Nuclear Energy, Science, & Technology								
Operating Costs	0.6	0.5	1.4	1.1	1.1	1.1	1.1	1.1
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.6	0.5	1.4	1.1	1.1	1.1	1.1	1.1
Direct Personnel	2.3	1.3	8.9	7.5	7.5	7.5	7.5	7.5
General Purpose Facilities	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a]For FY 2002 and FY 2003, 2.1% escalation for operating expenses and 4.5% for pay and personnel-related items.
[b]FY 2004 and beyond in constant FY 2003 dollars.
[c]Costs are under $50,000.

Table 5.1-14. Naval Reactors detailed resource breakout by program element (in $M; personnel in FTEs).								
Major Program	FY 2000 BO	FY 2001 BO	FY 2002[a] BA	FY 2003[a] BA	FY 2004[b] BA	FY 2005[b] BA	FY 2006[b] BA	FY 2007[b] BA
Naval Reactors Development–AJ								
Operating Costs	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Direct Personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Purpose Facilities	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a]For FY 2002 and FY 2003, 2.1% escalation for operating expenses and 4.5% for pay and personnel-related items.
[b]FY 2004 and beyond in constant FY 2003 dollars.

Table 5.1-15. Fossil Energy detailed resource breakout by program element (in $M; personnel in FTEs).

Major Program	FY 2000 BO	FY 2001 BO	FY 2002[a] BA	FY 2003[a] BA	FY 2004[b] BA	FY 2005[b] BA	FY 2006[b] BA	FY 2007[b] BA
Coal & Power Systems–AA								
Operating Costs	0.1	1.2	3.0	1.0	1.0	1.0	1.0	1.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.1	1.2	3.0	1.0	1.0	1.0	1.0	1.0
Direct Personnel	0.3	2.2	9.9	2.9	2.9	2.9	2.9	2.9
Natural Gas Research–AB05								
Operating Costs	0.8	0.4	1.4	2.3	2.3	2.3	2.3	2.3
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.8	0.4	1.4	2.3	2.3	2.3	2.3	2.3
Direct Personnel	1.1	0.9	5.0	8.3	8.3	8.3	8.3	8.3
Fuel Cells–AB45								
Operating Costs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Exploration & Production–AC1005								
Operating Costs	1.6	0.9	1.2	1.2	1.2	1.2	1.2	1.2
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	1.6	0.9	1.2	1.2	1.2	1.2	1.2	1.2
Direct Personnel	4.8	3.2	6.3	7.1	7.1	7.1	7.1	7.1
Effective Environmental Protection–AC1015								
Operating Costs	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	0.5	0.6	0.0	0.0	0.0	0.0	0.0	0.0
Emerging Processing Tech. App.–AC1020								
Operating Costs	0.1	0.0	0.2	0.1	0.1	0.1	0.1	0.1
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.1	0.0	0.2	0.1	0.1	0.1	0.1	0.1
Direct Personnel	0.3	0.0	1.0	0.6	0.6	0.6	0.6	0.6

Table 5.1-15, continued. Fossil Energy detailed resource breakout by program element (in $M; personnel in FTEs).

Major Program	FY 2000 BO	FY 2001 BO	FY 2002[a] BA	FY 2003[a] BA	FY 2004[b] BA	FY 2005[b] BA	FY 2006[b] BA	FY 2007[b] BA
Advanced Metallurgical Processes–AE10								
Operating Costs	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Total Fossil Energy								
Operating Costs	2.7	2.7	5.8	4.6	4.6	4.6	4.6	4.6
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	2.7	2.7	5.8	4.6	4.6	4.6	4.6	4.6
Direct Personnel	7.1	7.2	22.2	18.9	18.9	18.9	18.9	18.9
General Purpose Facilities	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a]For FY 2002 and FY 2003, 2.1% escalation for operating expenses and 4.5% for pay and personnel-related items.
[b]FY 2004 and beyond in constant FY 2003 dollars.

Table 5.1-16. Energy Efficiency & Renewable Energy detailed resource breakout by program element (in $M; personnel in FTEs).

Major Program	FY 2000 BO	FY 2001 BO	FY 2002[a] BA	FY 2003[a] BA	FY 2004[b] BA	FY 2005[b] BA	FY 2006[b] BA	FY 2007[b] BA
Industries of the Future—ED18/19								
Operating Costs	0.5	0.3	0.4	0.2	0.2	0.2	0.2	0.2
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.5	0.3	0.4	0.2	0.2	0.2	0.2	0.2
Direct Personnel	1.4	0.8	1.1	0.3	0.3	0.3	0.3	0.3
Transportation Sector–EE								
Operating Costs	3.9	2.9	4.3	4.2	4.2	4.2	4.2	4.2
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	3.9	2.9	4.3	4.2	4.2	4.2	4.2	4.2
Direct Personnel	11.2	6.1	15.6	14.0	14.0	14.0	14.0	14.0
Federal Energy Management Program–EL								
Operating Costs	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Direct Personnel	0.0	0.3	1.0	0.5	0.5	0.5	0.5	0.5
Solar & Renewable Resource Technologies–EB								
Operating Costs	3.3	3.1	4.6	6.0	6.0	6.0	6.0	6.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	3.3	3.1	4.6	6.0	6.0	6.0	6.0	6.0
Direct Personnel	10.6	9.9	15.2	20.8	20.8	20.8	20.8	20.8
In-House Energy Management–WB								
Operating Costs	0.0	0.0	0.1	0.2	0.2	0.2	0.2	0.2
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.0	0.2	0.1	0.2	0.2	0.2	0.2	0.2
Direct Personnel	0.0	0.0	0.3	0.9	0.9	0.9	0.9	0.9

Table 5.1-16, continued. Energy Efficiency and Renewable Energy detailed resource breakout by program element (in $M; personnel in FTEs).

Major Program	FY 2000 BO	FY 2001 BO	FY 2002[a] BA	FY 2003[a] BA	FY 2004[b] BA	FY 2005[b] BA	FY 2006[b] BA	FY 2007[b] BA
Total Energy Efficiency & Renewable Energy								
Operating Costs	7.7	6.3	9.5	10.7	10.7	10.7	10.7	10.7
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	7.7	6.5	9.5	10.7	10.7	10.7	10.7	10.7
Direct Personnel	23.2	16.8	33.2	36.5	36.5	36.5	36.5	36.5
General Purpose Facilities	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a]For FY 2002 and FY 2003, 2.1% escalation for operating expenses and 4.5% for pay and personnel-related items.
[b]FY 2004 and beyond in constant FY 2003 dollars.

Table 5.1-17. Management and Administration detailed resource breakout by program element (in $M; personnel in FTEs).

Major Program	FY 2000 BO	FY 2001 BO	FY 2002[a] BA	FY 2003[a] BA	FY 2004[b] BA	FY 2005[b] BA	FY 2006[b] BA	FY 2007[b] BA
Related Expenses–Contractual Services–WM10								
Operating Costs	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Purpose Facilities	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a]For FY 2002 and FY 2003, 2.1% escalation for operating expenses and 4.5% for pay and personnel-related items.
[b]FY 2004 and beyond in constant FY 2003 dollars.

Table 5.1-18. Policy detailed resource breakout by program element (in $M; personnel in FTEs).

Major Program	FY 2000 BO	FY 2001 BO	FY 2002[a] BA	FY 2003[a] BA	FY 2004[b] BA	FY 2005[b] BA	FY 2006[b] BA	FY 2007[b] BA
Policy, Analysis, & System Studies								
Operating Costs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding[c]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Purpose Facilities	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a]For FY 2002 and FY 2003, 2.1% escalation for operating expenses and 4.5% for pay and personnel-related items.
[b]FY 2004 and beyond in constant FY 2003 dollars.
[c]Costs are under $50,000.

Table 5.1-19. Civilian Radioactive Waste Management detailed resource breakout by program element (in $M; personnel in FTEs).

Major Program	FY 2000 BO	FY 2001 BO	FY 2002[a] BA	FY 2003[a] BA	FY 2004[b] BA	FY 2005[b] BA	FY 2006[b] BA	FY 2007[b] BA
Waste Management System–DF								
Operating Costs	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Direct Personnel	0.3	0.4	2.1	2.1	2.1	2.1	2.1	2.1
General Purpose Facilities	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a]For FY 2002 and FY 2003, 2.1% escalation for operating expenses and 4.5% for pay and personnel-related items.
[b]FY 2004 and beyond in constant FY 2003 dollars.

Table 5.1-20. Chief Financial Officer detailed resource breakout by program element (in $M; personnel in FTEs).

Major Program	FY 2000 BO	FY 2001 BO	FY 2002[a] BA	FY 2003[a] BA	FY 2004[b] BA	FY 2005[b] BA	FY 2006[b] BA	FY 2007[b] BA
Costs Associated with Safeguards & Security Activities Attributed to Work for Others–WN05[c]								
Operating Costs	0.0	9.0	13.7	14.1	14.1	14.1	14.1	14.1
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	0.0	9.0	13.7	14.1	14.1	14.1	14.1	14.1
Direct Personnel[d]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Purpose Facilities	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Proposed Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a]For FY 2002 and FY 2003, 2.1% escalation for operating expenses and 4.5% for pay and personnel-related items.
[b]FY 2004 and beyond in constant FY 2003 dollars.
[c]WN05 represents WFO allocation of Safeguards & Security Program.
[d]FTEs for WN05 in B&R FS — Safeguards & Security in Defense Programs.

Table 5.1-21. DOE WFO Facilities/Field Offices detailed resource breakout by program element (in $M; personnel in FTEs).

Major Program	FY 2000 BO	FY 2001 BO	FY 2002[a] BA	FY 2003[a] BA	FY 2004[b] BA	FY 2005[b] BA	FY 2006[b] BA	FY 2007[b] BA
Work-for-Others—DOE Integrated Contractors								
Operating Costs	32.3	28.6	30.2	22.3	22.3	22.3	22.3	22.3
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	32.3	28.6	30.2	22.3	22.3	22.3	22.3	22.3
Direct Personnel	117.4	83.8	84.1	58.1	58.1	58.1	58.1	58.1
Work for Other DOE Installations								
Operating Costs	51.7	57.1	75.4	73.7	73.7	73.7	73.7	73.7
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	51.7	57.1	75.4	73.7	73.7	73.7	73.7	73.7
Direct Personnel	171.8	167.2	209.9	191.9	191.9	191.9	191.9	191.9
Total WFO DOE Facilities/Field Offices								
Operating Costs	84.0	85.7	105.6	96.0	96.0	96.0	96.0	96.0
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Cost/Funding	84.0	85.7	105.6	96.0	96.0	96.0	96.0	96.0
Direct Personnel	289.2	251.0	294.0	250.0	250.0	250.0	250.0	250.0

[a]For FY 2002 and FY 2003, 2.1% escalation for operating expenses and 4.5% for pay and personnel-related items.
[b]FY 2004 and beyond in constant FY 2003 dollars.

Table 5.1-22. Non-DOE WFO detailed resource breakout by program element (in $M; personnel in FTEs).

Major Program	FY 2000 BO	FY 2001 BO	FY 2002[a] BA	FY 2003[a] BA	FY 2004[b] BA	FY 2005[b] BA	FY 2006[b] BA	FY 2007[b] BA
Department of Defense (DoD)								
Air Force	9.8	6.0	2.5	1.3	1.3	1.3	1.3	1.3
Army	21.2	18.2	17.3	24.5	24.5	24.5	24.5	24.5
Navy	7.0	7.2	11.9	21.7	21.7	21.7	21.7	21.7
Office of the Secretary of Defense (OSD)	6.5	5.0	6.7	7.5	7.5	7.5	7.5	7.5
BMDO	0.0	1.8	1.0	0.4	0.4	0.4	0.4	0.4
DTRA	10.4	12.4	3.6	3.8	3.8	3.8	3.8	3.8
DARPA	4.7	5.4	13.9	18.8	18.8	18.8	18.8	18.8
Other DoD	8.2	2.3	3.2	2.7	2.7	2.7	2.7	2.7
SERDP	0.4	0.1	0.1	0.0	0.0	0.0	0.0	0.0
OFA—Defense-Related	20.3	16.7	61.0	63.9	63.9	63.9	63.9	63.9
Total Department of Defense	88.5	75.1	121.2	144.6	144.6	144.6	144.6	144.6
Non-DoD Federal								
NRC	0.9	0.9	2.2	1.2	1.2	1.2	1.2	1.2
NIH	0.0	6.6	11.1	11.0	11.0	11.0	11.0	11.0
HHS	7.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NASA	3.5	2.1	3.3	1.9	1.9	1.9	1.9	1.9
DOI	0.6	0.2	0.4	0.4	0.4	0.4	0.4	0.4
DOS	0.6	0.5	0.2	0.0	0.0	0.0	0.0	0.0
DOT	0.6	1.7	0.2	0.5	0.5	0.5	0.5	0.5
OFA—Energy Research	0.8	2.6	1.1	1.1	1.1	1.1	1.1	1.1
Total Non-DoD Federal	14.5	14.6	19.5	16.1	16.1	16.1	16.1	16.1
Other Federal Non-Contract	2.2	1.4	0.0	0.0	0.0	0.0	0.0	0.0
Total Reimbursable WFO Federal Agencies	105.2	91.1	140.7	160.7	160.7	160.7	160.7	160.7
Non-Federal WFO	47.3	39.9	47.2	36.1	36.1	36.1	36.1	36.1
Total Non-DOE WFO	152.5	131.0	187.9	196.8	196.8	196.8	196.8	196.8
Direct Personnel	416.4	354.2	560.0	550.0	550.0	550.0	550.0	550.0

[a]For FY 2002 and FY 2003, 2.1% escalation for operating expenses and 4.5% for pay and personnel-related items.
[b]FY 2004 and beyond in constant FY 2003 dollars.

Table 5-2. Small and Disadvantaged Business Procurement FY 2000[a] (in $M).

Procurement Category	FY 1998	FY 1999	FY 2000	FY 2001
Procurement from Small and Disadvantaged Businesses	43.9	45.0	184.1	168.9
Percent of Annual Procurement	12.1%	15.9%	39.1%	39.9%

[a]Prior to FY 2000, the calculation was made for businesses that were both small and disadvantaged.

5.2 Organization chart

Director **C. Bruce Tarter**		
Deputy Director Science and Technology **Jeffrey Wadsworth**	Laboratory Executive Officer **Ronald W. Cochran**	Deputy Director Strategic Operations **Michael R. Anastasio**
Associate Deputy Director Science and Technology **Leland W. Younker**	Chief Financial Officer **Phillip A. Schultz**	Associate Deputy Director Strategic Operations **Merna Hurd**

Associate Director Defense and Nuclear Technologies **Bruce T. Goodwin**	Associate Director National Ignition Facility Programs **George H. Miller**	Associate Director Nonproliferation, Arms Control, and International Security **Wayne J. Shotts**
Associate Director Energy and Environment **C. K. Chou**	Associate Director Physics and Advanced Technologies **William H. Goldstein**	Associate Director Biology and Biotechnology Research **Berthold W. Weinstein (Acting)**
Associate Director Chemistry and Materials Science **Harold C. Graboske, Jr.**	Associate Director Engineering **Jens P. Mahler (Acting)**	Associate Director Computation **Dona L. Crawford**
Associate Director Safety, Security, and Environmental Protection **Dennis K. Fisher**	Associate Director Administrationn **Janet G. Tulk**	Associate Director Laboratory Services **J. Steve Hunt**

5.3 Publications and Internet Addresses

General information about the Laboratory's work may be found electronically on the World Wide Web through the Laboratory's home page at www.llnl.gov/. Other references called out in this Institutional Plan are shown below.

Please direct requests for hard copies of Livermore publications to:

Ellen Bradley
Off-Site Requests Coordinator
Lawrence Livermore National Laboratory
P.O. Box 808, L-658
Livermore, CA 94551
Phone 925-422-5820

5.3.1 Referenced Publications

Annual Performance Plan for FY 2002, U.S. Dept. of Energy, DOE-CR-0800-9, www.cfo.doe.gov/stratmgt/FY02-app.pdf.

Creating the Laboratory's Future: A Strategy for Lawrence Livermore National Laboratory, LLNL, Livermore, CA, UCRL-AR-12305, September 1997.

Department of Energy Strategic Plan: Providing America with Energy Security, National Security, Environmental Quality, and Science Leadership, U.S. Department of Energy, DOE/PO-00053, September 1997.

Department of Energy Strategic Plan: Strength through Science Powering the 21st Century, U.S. Department of Energy, September 2000, www.cfo.doe.gov/stratmgt/plan/doesplan.htm.

Integrated Safety Management System Plan Description, LLNL, Livermore, CA, UCRL-AR-132791, February 2000.

Laboratory Directed Research and Development FY 2000 Annual Report, LLNL, Livermore, CA, UCRL-LR-113717-00, 2000.

Laboratory Research and Development: Innovation and Creativity Supporting National Security; Livermore, Los Alamos, and Sandia National Laboratories; Los Alamos, NM, LALP-97, April 1997.

LLNL 1999 Executive Summary—Affirmative Action Plan for Women, Individuals with Disabilities, and Covered Veterans, LLNL, Livermore, CA, UCRL-AR-111638-99-EXE-SUM.

LLNL Comprehensive Site Plan, LLNL, Livermore, CA, UCRL-MI-110253-99, March 1999.

LLNL Site 300 Comprehensive Site Plan, LLNL, Livermore, CA, UCRL-MI-130630-00, August 2000.

National Energy Policy, National Energy Policy Development Group, May 2001, ISBN 0-16-050814-2, www.energy.gov/HQPress/releases01/maypr/national_energy_policy.pdf.

Science & Technology Review, LLNL, Livermore, CA, UCRL-52000; published 10 times per year beginning July 1995, www.llnl.gov/str/.

Site Annual Environmental Report, LLNL, Livermore, CA, UCRL-50027-99, September 1999.

Stockpile Stewardship Plan: Second Annual Update (FY 1999), U.S. Department of Energy Office of Defense Programs, April 1998.

The National Ignition Facility and the Stockpile Stewardship Program, U.S. Department of Energy, Office of Defense Programs, DOE/DP-0143, April 2000.

2020 Foresight: Forging the Future of LLNL (The Report of the Long-Range Strategy Project), LLNL, Livermore, CA, UCRL-LR-137882, January 2000.

5.3.2 *S&TR* Articles

Many scientific and technical topics in Sections 2, 3, and 4 have been discussed in fuller detail in the Laboratory's *Science & Technology Review* over the last few years. Article topics and their Internet addresses are listed below. Additional topics can be found using *S&TR*'s search engine. Hard copies are available through the Off-Site Requests Coordinator (address at left).

Section 2
- Stockpile Stewardship: www.llnl.gov/str/Alonso.html
- Nonproliferation Support: www.llnl.gov/str/Dunlop.html
- Enhanced Surveillance of Weapons: www.llnl.gov/str/Kolb.html
- Reducing the Threat of Biological Weapons: www.llnl.gov/str/Milan.html

2.1.2
- High Explosives for Surveillance: www.llnl.gov/str/Lundberg.html
- Enhanced Surveillance of Weapons: www.llnl.gov/str/Kolb.html
- High Explosives: www.llnl.gov/str/Grissom.html
- Materials Aging: www.llnl.gov/str/Lemay.html

2.1.3
- Subcritical Experiments: www.llnl.gov/str/Conrad.html

2.1.4
- ASCI White Supercomputing: www.llnl.gov/str/Seager.html
- Computer Simulations for ASCI: www.llnl.gov/str/Christensen.html
- Modeling High Explosives: www.llnl.gov/str/Simpson99.html
- Lasers for NIF: www.llnl.gov/str/Payne.html

• Laser Targets:
www.llnl.gov/str/Lowns.html
• NIF Laser Developments:
www.llnl.gov/str/Powell.html
• NIF Controls:
www.llnl.gov/str/Vanarsdall.html
• NIF Ignition Experiments:
www.llnl.gov/str/Haan.html
• TATB: www.llnl.gov/str/Pagoria.html

2.1.5
• Laser Ignition Experiments:
www.llnl.gov/str/Haan.html
• Lasers for NIF:
www.llnl.gov/str/Payne.html
• Laser Targets:
www.llnl.gov/str/Lowns.html
• Laser Developments for NIF:
www.llnl.gov/str/Powell.html
• National Ignition Facility Controls:
www.llnl.gov/str/Vanarsdall.html

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• ASCI White and Terascale Supercomputing:
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• Computer Simulations for ASCI:
www.llnl.gov/str/Christensen.html

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• Working with Russia:
www.llnl.gov/str/Dunlop2.html

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• Reducing the Threat of Biological Weapons: www.llnl.gov/str/Milan.html
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• Forensic Science Center:
www.llnl.gov/str/Andresenhi.html

Section 3
• Energy Overview at LLNL:
www.llnl.gov/str/Energy.html

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www.llnl.gov/str/Davis.html
• Simulations of Geologic Changes at Yucca Mountain:
www.llnl.gov/str/Glassley.html

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• Corsica: Simulations for Magnetic Energy: www.llnl.gov/str/Cohen.html
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• Electromechanical Battery:
www.llnl.gov/str/pdfs/04_96.2.pdf
• Unitized Regenerative Fuel Cell:
www.llnl.gov/str/Mitlit.html
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• ARAC Forewarns of Hazards:
www.llnl.gov/str/Baskett.html
• Environmental Cleanup Basics:
www.llnl.gov/str/Jackson.html
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www.llnl.gov/str/Newmark.html

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www.llnl.gov/str/Balhorn.html
• DNA Sequencing:
www.llnl.gov/str/Ashworth.html
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• Structural Biology:
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• Kidney Gene with Human Genome Program: www.llnl.gov/str/Hamza.html
• Computational Biochemistry:
www.llnl.gov/str/Balhorn.html

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• Osteoporosis:
www.llnl.gov/str/pdfs/06_96.3.pdf
• Ergonomics Research:
www.llnl.gov/str/Burastero.html
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www.llnl.gov/str/Moses.html
• Technology for Stroke Attack:
www.llnl.gov/str/Fitch.html

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www.llnl.gov/str/MPerry.html

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• 1997 R&D 100 Awards:
www.llnl.gov/str/10.97.html
• 1998 R&D 100 Awards:
www.llnl.gov/str/10.98.html
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www.llnl.gov/str/Roberson.html
• 2001 R&D 100 Awards: www.llnl.gov/str/September01/Sept01.html

3.4.2
• Methane Hydrate Surprises:
www.llnl.gov/str/Durham.html
• B-Factory:
www.llnl.gov/str/VanBib.html
• Visalia Cleanup:
www.llnl.gov/str/Newmark.html

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• Laser Collaboration with University of Rochester: www.llnl.gov/str/Olivier.html
• Center for Accelerator Mass Spectrometry:
www.llnl.gov/str/Holloway.html
• Diamond Anvil Cell:
www.llnl.gov/str/pdfs/03_96.2.pdf
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www.llnl.gov/str/Howell.html
• Bridge Seismology and Modeling:
www.llnl.gov/str/McCallen.html

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